REPORT

OF THE

TWENTY-SEVENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT DUBLIN IN AUGUST AND SEPTEMBER 1857.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1858.

PRINTED BY
RICHARD TAYLOR AND WILLIAM FRANCIS,
RED LION COURT, FLEET STREET.

ALERE FLAMMAM.

CONTENTS.

REPORTS OF RESEARCHES IN SCIENCE.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Mathematics.

Light, Optical Instruments.

METEOROLOGY.

CHEMISTRY.

GEOLOGY.

BOTANY AND ZOOLOGY, INCLUDING PHYSIOLOGY.

BOTANY.

ZOOLOGY.

Physiology.

Miscellaneous.

GEOGRAPHY AND ETHNOLOGY.

STATISTICS.

MECHANICAL SCIENCE.

APPENDIX.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

All Persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

Associates for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes :—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz. :—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.
   New Life Members who have paid Ten Pounds as a composition.
   Annual Members who have not intermitted their Annual Subscription.
2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.
   Annual Members, who have intermitted their Annual Subscription.
   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain*, at one-third of the Publication Price. Application to be made (by letter) to Messrs. Taylor & Francis, Red Lion Court, Fleet St., London.

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons :—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.

2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.

3. Office-bearers for the time being, or Delegates, altogether, not exceeding three in number, from any Philosophical Society publishing Transactions.
4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.
5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the Meeting of the year by the President and General Secretaries.
6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex-officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee, unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S.L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MAKDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robison, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. .... YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 31, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Prof. Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Prof. Jellett, F.T.C.D. W. Neilson Hancock, LL.D.
RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge. James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.

THE GENERAL TREASURER'S ACCOUNT from 6th August 1856 (commencement of Cheltenham Meeting) to 26th August 1857 (at Dublin).

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance brought on from last Account				208	2	4
Life Compositions at Cheltenham Meeting and since				188	0	0
Annual Subscriptions, ditto ditto				301	1	0
Associates' Tickets, ditto				412	0	0
Ladies' Tickets, ditto				346	0	0
Interest allowed by Bank at Glasgow				9	0	10
12 Months' Dividends on £5000 3 per cent. Consols				142	16	3
From Sale of Publications—						
viz. Reports of Meetings	108	8	7			
Catalogues of Stars, Dove's Lines	44	11	6			
				153	0	1
				£1760	0	6

EDWIN LANKESTER,
JAMES YATES,
NORTON SHAW, } *Auditors.*

PAYMENTS.

	£	s.	d.	£	s.	d.
By paid Expenses of Cheltenham Meeting, Sundry Printing, Binding, Advertising, and Incidental Expenses made by General Treasurer and Local Treasurers				334	4	4
Printing Report of the Twenty-Fifth Meeting, Engraving, &c.				444	3	0
Salaries for 12 months				350	0	0
Maintaining the Establishment of Kew Observatory				350	0	0
Earthquake Waves' Experiments				40	0	0
Dredging near Belfast				10	0	0
Ditto on the West Coast of Scotland				10	0	0
Investigations into the Mollusca of California				10	0	0
Experiments on Flax				5	0	0
Natural History of Madagascar				20	0	0
Researches on British Annelida				25	0	0
Report on Natural Products imported into Liverpool				10	0	0
Artificial propagation of Salmon				10	0	0
Temperature of Mines				7	8	0
Thermometers for Subterranean Observations				5	7	4
Life Boats				5	0	0
Balance at the Bankers	£111	2	10			
Ditto due from Treasurer and Local Treasurers	12	15	0			
				123	17	10
				£1760	0	6

II. Table showing the Names of Members of the British Association who have served on the Council in former years.

Acland, Sir Thomas D., Bart., F.R.S.
Acland, Professor H. W., M.D., F.R.S.
Adams, J. Couch, M.A., F.R.S.
Adamson, John, Esq., F.L.S.
Ainslie, Rev. Gilbert, D.D., Master of Pembroke Hall, Cambridge.
Airy, G. B., D.C.L., F.R.S., Astronomer Royal.
Alison, Professor W. P., M.D., F.R.S.E.
Ansted, Professor D. T., M.A., F.R.S.
Argyll, George Douglas, Duke of, F.R.S.
Arnott, Neil, M.D., F.R.S.
Ashburton, William Bingham, Lord, D.C.L.
Atkinson, Rt. Hon. R., Lord Mayor of Dublin.
Babbage, Charles, Esq., M.A., F.R.S.
Babington, C. C., Esq., M.A., F.R.S.
Baily, Francis, Esq., F.R.S. (deceased).
Baker, Thomas Barwick Lloyd, Esq.
Balfour, Professor John H., M.D., F.R.S.
Barker, George, Esq., F.R.S. (deceased).
Bell, Professor Thomas, Pres. L.S., F.R.S.
Beechey, Rear-Admiral, F.R.S. (deceased).
Bengough, George, Esq.
Bentham, George, Esq., F.L.S.
Bigge, Charles, Esq.
Blakiston, Peyton, M.D., F.R.S.
Boileau, Sir John P., Bart., F.R.S.
Boyle, Rt. Hon. D., Lord Justice-Genl. (decd).
Brady, The Rt. Hon. Maziere, M.R.I.A., Lord Chancellor of Ireland.
Brand, William, Esq.
Breadalbane, John, Marquis of, K.T., F.R.S.
Brewster, Sir David, K.H., D.C.L., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, St. Andrews.
Brisbane, General Sir Thomas M., Bart., K.C.B., G.C.H., D.C.L., F.R.S.
Brooke, Charles, B.A., F.R.S.
Brown, Robert, D.C.L., F.R.S. (deceased).
Brunel, Sir M. I., F.R.S. (deceased).
Buckland, Very Rev. William, D.D., F.R.S., Dean of Westminster (deceased).
Bute, John, Marquis of, K.T. (deceased).
Carlisle, George Will. Fred., Earl of, F.R.S.
Carson, Rev. Joseph, F.T.C.D.
Cathcart, Lt.-Gen., Earl of, K.C.B., F.R.S.E.
Chalmers, Rev. T., D.D. (deceased).
Chance, James, Esq.
Chester, John Graham, D.D., Lord Bishop of.
Christie, Professor S. H., M.A., F.R.S.
Clare, Peter, Esq., F.R.A.S. (deceased).
Clark, Rev. Prof., M.D., F.R.S. (Cambridge.)
Clark, Henry, M.D.
Clark, G. T., Esq.
Clear, William, Esq. (deceased).
Clerke, Major S., K.H., R.E., F.R.S. (decd).
Clift, William, Esq., F.R.S. (deceased).
Close, Very Rev. F., M.A., Dean of Carlisle.
Cobbold, John Chevalier, Esq., M.P.
Colquhoun, J. C., Esq., M.P. (deceased).
Conybeare, Very Rev. W. D., Dean of Llandaff (deceased).
Corrie, John, Esq., F.R.S. (deceased).
Crum, Walter, Esq., F.R.S.
Currie, William Wallace, Esq. (deceased).
Dalton, John, D.C.L., F.R.S. (deceased).
Daniell, Professor J. F., F.R.S. (deceased).
Dartmouth, William, Earl of, D.C.L., F.R.S.
Darwin, Charles, Esq., M.A., F.R.S.
Daubeny, Prof. Charles G. B., M.D., F.R.S.
DelaBeche, Sir H. T., C.B., F.R.S., Director-Gen. Geol. Surv. United Kingdom (decd).
Devonshire, William, Duke of, M.A., F.R.S.
Dillwyn, Lewis W., Esq., F.R.S. (deceased).
Drinkwater, J. E., Esq. (deceased).
Ducie, The Earl, F.R.S.
Dunraven, The Earl of, F.R.S.
Egerton, Sir P. de M. Grey, Bart., M.P., F.R.S.
Eliot, Lord, M.P.
Ellesmere, Francis, Earl of, F.G.S. (decd).
Enniskillen, William, Earl of, D.C.L., F.R.S.
Estcourt, T. G. B., D.C.L. (deceased).
Faraday, Professor, D.C.L., F.R.S.
Fitzwilliam, The Earl, D.C.L., F.R.S. (decd).
Fleming, W., M.D.
Fletcher, Bell, M.D.
Forbes, Charles, Esq. (deceased).
Forbes, Prof. Edward, F.R.S. (deceased).
Forbes, Prof. J. D., F.R.S., Sec. R.S.E.
Fox, Robert Were, Esq., F.R.S.
Frost, Charles, F.S.A.
Gassiot, John P., Esq., F.R.S.
Gilbert, Davies, D.C.L., F.R.S. (deceased).
Graham, T., M.A., F.R.S., Master of the Mint.
Gray, John E., Esq., Ph.D., F.R.S.
Gray, Jonathan, Esq. (deceased).
Gray, William, Esq., F.G.S.
Green, Prof. Joseph Henry, D.C.L., F.R.S.
Greenough, G. B., Esq., F.R.S. (deceased).
Griffith, Sir R. Griffith, Bt., LL.D., M.R.I.A.
Grove, W. R., Esq., M.A., F.R.S.
Hallam, Henry, Esq., M.A., F.R.S.
Hamilton, W. J., Esq., F.R.S., For. Sec. G.S.
Hamilton, Sir Wm. R., LL.D., Astronomer Royal of Ireland, M.R.I.A., F.R.A.S.
Harcourt, Rev. Wm. Vernon, M.A., F.R.S.
Hardwicke, Charles Philip, Earl of, F.R.S.
Harford, J. S., D.C.L., F.R.S.
Harris, Sir W. Snow, F.R.S.
Harrowby, The Earl of, F.R.S.
Hatfeild, William, Esq., F.G.S. (deceased).
Henry, W. C., M.D., F.R.S.
Henry, Rev. P. S., D.D., President of Queen's [Col., Belfast.
Henslow, Rev. Professor, M.A., F.L.S.
Herbert, Hon. and Very Rev. Wm., LL.D., F.L.S., Dean of Manchester (decd).
Herschel, Sir John F. W., Bart., D.C.L., F.R.S.
Heywood, Sir Benjamin, Bart., F.R.S.
Heywood, James, Esq., F.R.S.
Hill, Rev. Edward, M.A., F.G.S.
Hincks, Rev. Edward, D.D., M.R.I.A.
Hinds, S., D.D., late Lord Bishop of Norwich.
Hodgkin, Thomas, M.D.
Hodgkinson, Professor Eaton, F.R.S.
Hodgson, Joseph, Esq., F.R.S.
Hooker, Sir William J., LL.D., F.R.S.
Hope, Rev. F. W., M.A., F.R.S.
Hopkins, William, Esq., M.A., F.R.S.
Horner, Leonard, Esq., F.R.S., F.G.S.
Hovenden, V. F., Esq., M.A.
Hutton, Robert, Esq., F.G.S.
Hutton, William, Esq., F.G.S.
Ibbetson, Capt. L. L. Boscawen, K.R.E., F.G.S.
Inglis, Sir R. H., Bart., D.C.L., M.P., (decd).
Jameson, Professor R., F.R.S. (deceased).
Jardine, Sir William, Bart., F.R.S.E.
Jeffreys, John Gwyn, Esq., F.R.S.
Jenyns, Rev. Leonard, F.L.S.
Jerrard, H. B., Esq.
Johnston, Right Hon. William, late Lord Provost of Edinburgh.
Johnston, Prof. J. F. W., M.A., F.R.S. (decd).
Kelcher, William, Esq. (deceased).
Kelland, Rev. Professor P., M.A.
Kildare, The Marquis of.

Lankester, Edwin, M.D., F.R.S.
Lansdowne, Hen., Marquis of, D.C.L., F.R.S.
Larcom, Lt.-Colonel, R.E., LL.D., F.R.S.
Lardner, Rev. Dr.
Lassell, William, Esq., F.R.S. L. & E.
Latham, R. G., M.D., F.R.S.
Lee, Very Rev. John, D.D., F.R.S.E., Principal of the University of Edinburgh.
Lee, Robert, M.D., F.R.S.
Lefevre, Right Hon. Charles Shaw, late Speaker of the House of Commons.
Lemon, Sir Charles, Bart., F.R.S.
Liddell, Andrew, Esq. (deceased).
Lindley, Professor John, Ph.D., F.R.S.
Listowel, The Earl of.
Lloyd, Rev. B., D.D., Provost of Trin. Coll. [Dublin (dec[d]).
Lloyd, Rev. H., D.D., D.C.L., F.R.S. L. & E.,
Londesborough, Lord, F.R.S.
Lubbock, Sir John W., Bart., M.A., F.R.S.
Luby, Rev. Thomas.
Lyell, Sir Charles, M.A., F.R.S.
MacCullagh, Prof., D.C.L., M.R.I.A. (dec[d]).
MacDonnell, Rev. R., D.D., M.R.I.A., Provost of Trinity College, Dublin.
Macfarlane, The Very Rev. Principal. (dec[d]).
MacLeay, William Sharp, Esq., F.L.S.
MacNeill, Professor Sir John, F.R.S.
Malahide, The Lord Talbot de.
Malcolm, Vice-Ad. Sir Charles, K.C.B. (dec[d]).
Maltby, Edward, D.D., F.R.S., late Lord Bishop of Durham.
Manchester, J. P. Lee, D.D., Lord Bishop of.
Meynell, Thomas, Esq., F.L.S.
Middleton, Sir William F. F., Bart.
Miller, Professor W. A., M.D., F.R.S.
Miller, Professor W. H., M.A., F R.S.
Moillet, J. D., Esq. (deceased).
Milnes, R. Monckton, Esq., D.C.L., M.P.
Moggridge, Matthew, Esq.
Moody, J. Sadleir, Esq.
Moody, T. H. C., Esq.
Moody, T. F., Esq.
Morley, The Earl of.
Moseley, Rev. Henry, M.A., F.R.S.
Mount-Edgecumbe, Ernest Augustus, Earl of.
Murchison, Sir Roderick I., G.C. St.S., F.R.S.
Neill, Patrick, M.D., F.R.S.E.
Nicol, D., M.D.
Nicol, Rev. J. P., LL.D.
Northampton, Spencer Joshua Alwyne, Marquis of, V.P.R.S. (deceased).
Northumberland, Hugh, Duke of, K.G., M.A., F.R.S. (deceased).
Ormerod, G. W., Esq., M.A., F.G.S.
Orpen, Thomas Herbert, M.D. (deceased).
Orpen, John H., LL.D.
Osler, Follett, Esq., F.R.S.
Owen, Professor Richd., M.D., D.C.L., F.R.S.
Oxford, Samuel Wilberforce, D.D., Lord Bishop of, F.R.S., F.G.S.
Palmerston, Viscount, G.C.B., M.P.
Peacock, Very Rev. G., D.D., Dean of Ely, F.R.S.
Peel, Rt. Hon. Sir R., Bart., M.P., D.C.L. (dec[d]).
Pendarves, E., Esq., F.R.S.
Phillips, Professor John, M.A., LL.D., F.R.S.
Pigott, The Rt. Hon. D. R., M.R.I.A., Lord Chief Baron of the Exchequer in Ireland.
Porter, G. R., Esq. (deceased).
Powell, Rev. Professor, M.A., F.R.S.
Prichard, J. C., M.D., F.R.S. (deceased).
Ramsay, Professor William, M.A.
Reid, Maj.-Gen. Sir W., K.C.B., R.E., F.R.S.
Rendlesham, Rt. Hon. Lord, M.P.
Rennie, George, Esq., F.R.S.
Rennie, Sir John, F.R.S.
Richardson, Sir John, M.D., C.B., F.R.S.
Ritchie, Rev. Prof., LL.D., F.R.S. (dec[d]).
Robinson, Rev. J., D.D.
Robinson, Rev. T. R., D.D., F.R.A.S.
Robison, Sir John, Sec.R.S.Edin. (deceased).
Roche, James, Esq.
Roget, Peter Mark, M.D., F.R.S.
Ronalds, Francis, F.R.S.
Rosebery, The Earl of, K.T., D.C.L., F.R.S.
Ross, Rear-Ad. Sir J. C., R.N., D.C.L., F.R.S.
Rosse, Wm., Earl of, M.A., F.R.S., M.R.I.A.
Royle, Professor John F., M.D., F.R.S.
Russell, James, Esq. (deceased).
Russell, J. Scott, Esq., F.R.S.
Sabine, Maj.-Gen., R.A., D.C.L., Treas. & [V.P.R.S.
Sanders, William, Esq., F.G.S.
Scoresby, Rev. W., D.D., F.R.S. (deceased).
Sedgwick, Rev. Prof. Adam, M.A., F.R.S.
Selby, Prideaux John, Esq., F.R.S.E.
Sharpey, Professor, M.D., Sec.R.S.
Smith, Lieut.-Colonel C. Hamilton, F.R.S.
Smith, James, F.R.S. L. & E.
Spence, William, Esq., F.R.S.
Stanley, Edward, D.D., F.R.S., late Lord Bishop of Norwich (deceased).
Staunton, Sir G. T., Bt., M.P., D.C.L., F.R.S.
St. David's, C. Thirlwall, D.D., Lord Bishop of.
Stevelly, Professor John, LL.D.
Stokes, Professor G. G., Sec.R.S.
Strang, John, Esq., LL.D.
Strickland, Hugh E., Esq., F.R.S. (deceased).
Sykes, Colonel W. H., M.P., F.R.S.
Symonds, B. P., D.D., Vice-Chancellor of the University of Oxford.
Talbot, W. H. Fox, Esq., M.A., F.R.S.
Tayler, Rev. John James, B.A.
Taylor, John, Esq., F.R.S.
Taylor, Richard, Esq., F.G.S.
Thompson, William, Esq., F.L.S. (deceased).
Thomson, Professor William, M.A., F.R.S.
Tindal, Captain, R.N.
Tite, William, Esq., M.P., F.R.S.
Tod, James, Esq., F.R.S.E.
Tooke, Thomas, F.R.S. (deceased).
Traill, J. S., M.D. (deceased).
Turner, Edward, M.D., F.R.S. (deceased).
Turner, Samuel, Esq., F.R.S., F.G.S. (dec[d]).
Turner, Rev. W.
Tyndall, Professor, F.R.S.
Vigors, N. A., D.C.L., F.L.S. (deceased).
Vivian, J. H., M.P., F.R.S. (deceased).
Walker, James, Esq., F.R.S.
Walker, Joseph N., Esq., F.G.S.
Walker, Rev. Professor Robert, M.A., F.R.S.
Warburton, Henry, Esq., M.A., F.R.S.
Washington, Captain, R.N., F.R.S.
Webster, Thomas, M.A., F.R.S.
West, William, Esq., F.R.S. (deceased).
Western, Thomas Burch, Esq.
Wharncliffe, John Stuart, Lord, F.R.S.
Wheatstone, Professor Charles, F.R.S.
Whewell, Rev. William, D.D., F.R.S., Master of Trinity College, Cambridge.
Williams, Prof. Charles J. B., M.D., F.R.S.
Willis, Rev. Professor Robert, M.A., F.R.S.
Wills, William, Esq., F.G.S.
Winchester, John, Marquis of.
Woollcombe, Henry, Esq., F.S.A. (deceased).
Wrottesley, John, Lord, M.A., Pres.R.S.
Yarborough, The Earl of, D.C.L.
Yarrell, William, Esq., F.L.S. (deceased).
Yates, James, Esq., M.A., F.R.S.
Yates, J. B., Esq., F.S.A., F.R.G.S. (dec[d]).

OFFICERS AND COUNCIL, 1857-58.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE DUBLIN MEETING.

SECTION A.—MATHEMATICS AND PHYSICS.

President.—Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.

Vice-Presidents.—J. C. Adams, F.R.S.; Rev. Professor Graves, Sec. R.I.A.; Sir W. R. Hamilton, LL.D., M.R.I.A.; Rev. George Salmon, D.D., M.R.I.A.; Rev. W. Whewell, D.D., F.R.S.; Lord Wrottesley, President of the Royal Society.

Secretaries.—Professor Curtis, A.M; Professor Hennessy, M.R.I.A.; P. A. Ninnis, B.A.; W. J. Macquorn Rankine, F.R.S.; Professor Stevelly, LL.D.

SECTION B.—CHEMISTRY AND MINERALOGY, INCLUDING THEIR APPLICATIONS TO AGRICULTURE AND THE ARTS.

President.—Professor Apjohn, M.D., F.R.S., M.R.I.A.

Vice-Presidents.—Professor T. Andrews, M.D., F.R.S., M.R.I.A.; Professor E. Davy, F.R.S., M.R.I.A.; Rev. Wm. Vernon Harcourt, F.R.S.; Professor W. A. Miller, M.D., F.R.S.; Professor G. Wilson, M.D., F.R.S.E.

Secretaries.—Dr. Gladstone, F.R.S.; Professor W. K. Sullivan, M.R.I.A.; Dr. E. W. Davy, M.R.I.A.

SECTION C.—GEOLOGY.

President.—The Lord Talbot de Malahide, President of the Geological Society of Dublin.

Vice-Presidents.—Richard Griffith, LL.D.; Professor Haughton, M.R.I.A., F.G.S.; J. Beete Jukes, F.R.S., M.R.I.A.; Thomas Oldham, F.R.S., M.R.I.A.; Colonel Portlock, R.E., F.R.S., M.R.I.A.

Secretaries.—Professor Harkness, F.R.S.; Gilbert Sanders, M.R.I.A.; Robert H. Scott, Esq.

SECTION D.—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

President.—Professor William Henry Harvey, M.D., M.R.I.A.

Vice-Presidents.—Professor G.J. Allman, M.D., F.R.S., M.R.I.A.; Professor C.G. Daubeny, M.D., F.R.S.; A. H. Halliday, M.R.I.A., F.L.S.; Professor Robert Harrison, M. D., M.R.I.A.; W. Ogilby, F.L.S., M.R.I.A.; Sir John Richardson, F.R.S.

Secretaries.—Professor John R. Kinahan, M.B., M.R.I.A.; Edwin Lankester, M.D., F.R.S.; Robert Patterson, M.R.I.A.; William Edward Steele, M.D.

SUB-SECTION D.—PHYSIOLOGICAL SCIENCE.

President.—Robert Harrison, M.D., M.R.I.A., Professor of Anatomy and Physiology, T.C.D.

Vice-Presidents.—Sir H. Marsh, Bart., M.R.I.A.; Professor Hugh Carlile, M.R.I.A.; Professor F. C. Faye, Christiania; Dr. Jacob; Dr. Laycock, Professor of Practice of Medicine, University of Edinburgh; Sir Philip Crampton, Bart., F.R.S., M.R.I.A.

Secretaries.—Robert D. Lyons, M.B., M.R.I.A.; Professor Redfern.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

President.—Rev. James Henthorn Todd, D.D., Pres. R.I.A.

Vice-Presidents.—Major-General Chesney, R.A., D.C.L., F.R.S.; John Crawford, F.R.G.S.; Rear-Admiral R. FitzRoy, F.R.S.; Rev. Edward Hincks, D.D.; Rev. Charles Wm. Wall, D.D., Vice Provost T.C.D., M.R.I.A.; Wm. R. Wilde, M.R.I.A.

Secretaries.—Richard Cull, F.S.A.; Samuel Ferguson, M.R.I.A.; Richard R. Madden, M.D., F.R.C.S. Eng.; Dr. Norton Shaw, Sec. R.G.S.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

President.—The Archbishop of Dublin, M.R.I.A.

Vice-Presidents.—Lord Monteagle, F.R.S.; Edwin Chadwick, C.B.; The Recorder of Birmingham; James A. Lawson, Q.C., LL.D., M.R.I.A.; Edward Baines, Esq.; John Strang, LL.D.; Wm. Donnelly, LL.D.; F. G. P. Neison, F.S.S.; James R. Napier.

Secretaries.—William Newmarch, F.S.S.; Professor Cairnes, M.R.I.A.; Henry Dix Hutton, LL.B.

SECTION G.—MECHANICAL SCIENCE.

President.—The Earl of Rosse, F.R.S., M.R.I.A.

Vice-Presidents.—George Rennie, F.R.S.; Robert Mallet, M. Inst. C.E., F.R.S., M.R.I.A.; Sir John Macneill, F.R.S., M.R.I.A.; John Scott Russell, F.R.S.; William Dargan, M.R.I.A.

Secretaries.—James Thompson, C.E.; William T. Doyne, M. Inst. C.E.; Henry Wright; Professor Downing, LL.D., M.R.I.A.; Alexander Tate, Secretary Inst. C.E.I.

CORRESPONDING MEMBERS.

Professor Agassiz, *Cambridge, Massachusetts.*
M. Babinet, *Paris.*
Dr. A. D. Bache, *Washington.*
Professor Balzani, *Kazan.*
Barth, Dr.
Mr. P. G. Bond, *Cambridge, U.S.*
M. Boutigny (d'Evreux).
Professor Braschmann, *Moscow.*
Chevalier Bunsen, *Heidelberg.*
Dr. Ferdinand Cohn, *Breslau.*
M. Antoine d'Abbadie.
M. De la Rive, *Geneva.*
Professor Dove, *Berlin.*
Professor Dumas, *Paris.*
Dr. J. Milne-Edwards, *Paris.*
Professor Ehrenberg, *Berlin.*
Dr. Eisenlohr, *Carlsruhe.*
Professor Encke, *Berlin.*
Dr. A. Erman, *Berlin.*
Professor Esmark, *Christiania.*
Professor G. Forchhammer, *Copenhagen.*
M. Léon Foucault, *Paris.*
Prof. E. Fremy, *Paris.*
M. Frisiani, *Milan.*
Professor Asa Gray, *Cambridge, U.S.*
Professor Henry, *Washington, U.S.*
Baron Alexander von Humboldt, *Berlin.*
M. Jacobi, *St. Petersburg.*
Prof. A. Kölliker, *Wurzburg.*
Prof. De Koninck, *Liège.*
Professor Kreil, *Vienna.*
Dr. A. Kupffer, *St. Petersburg.*
Dr. Lamont, *Munich.*
Prof. F. Lanza, *Spoleto.*
M. Le Verrier, *Paris.*
Baron von Liebig, *Munich.*
Baron de Sélys-Longchamps, *Liège.*
Professor Loomis, *New York.*
Professor Gustav Magnus, *Berlin.*
Professor Matteucci, *Pisa.*
Professor von Middendorff, *St. Petersburg.*
M. l'Abbé Moigno, *Paris.*
Professor M. Morren, *Liège.*
Professor Nilsson, *Sweden.*
Dr. N. Nordengsciold, *Finland.*
M. E. Peligot, *Paris.*
Viscenza Pisani, *Florence.*
Gustave Plaar, *Strasburg.*
Chevalier Plana, *Turin.*
Professor Plücker, *Bonn.*
M. Constant Prévost, *Paris.*
M. Quetelet, *Brussels.*
Prof. Retzius, *Stockholm.*
Professor C. Ritter, *Berlin.*
Professor H. D. Rogers, *Boston, U.S.*
Professor W. B. Rogers, *Boston, U.S.*
Professor H. Rose, *Berlin.*
Herman Schlagintweit, *Berlin.*
Robert Schlagintweit, *Berlin.*
Baron Senftenberg, *Bohemia.*
Dr. Siljestrom, *Stockholm.*
M. Struvè, *Pulkowa.*
Dr. Svanberg, *Stockholm.*
M. Pierre Tchihatchef.
Dr. Van der Hoeven, *Leyden.*
Baron Sartorius von Waltershausen, *Göttingen.*
Professor Wartmann, *Geneva.*

REPORT OF THE COUNCIL OF THE BRITISH ASSOCIATION AS PRESENTED TO THE GENERAL COMMITTEE AT DUBLIN, AUGUST 26TH, 1857.

I. With reference to the subjects referred to the Council by the General Committee at Cheltenham, the Council have to report as follows:—

a. The General Committee directed that copies of the two last Reports of the Parliamentary Committee should be transmitted to each Member of the General Committee, with a request that opinions might be expressed on the important subject, "Whether any measures could be adopted by the Government or Parliament that would improve the position of Science and its cultivators;" and that such opinions should be forwarded for the consideration of the Council before the 20th of September, 1856. This direction having been complied with, and a considerable number of letters expressing the opinions of individual Members of the General Committee having been received, the Council requested the Assistant-General Secretary to prepare a digest, and to make such an arrangement of the communications themselves as might best facilitate their full consideration at a Special Meeting of the Council in January, 1857. At this meeting, Lord Wrottesley, President of the Royal Society, being one of the Members

of the Council of the Association, communicated for the information of the Council, certain resolutions which had been adopted by the President and Council of the Royal Society, bearing on the same question; and after a full consideration of these resolutions, and of the opinions expressed in the letters of the individual Members of the General Committee of the Association, the Council adopted the following Minute, viz.—"That the Council concur generally in the course of proceeding which has been taken on this subject by the Royal Society, as now explained to them by the President of that Society." This Minute was communicated by order to the Royal Society, and the Resolutions have been since transmitted by Lord Wrottesley to Lord Palmerston, as having been adopted by the President and Council of the Royal Society and concurred in by the Council of the British Association.

b. The recommendation, that "the application to Government for an Expedition to complete our knowledge of the Tides be renewed," was referred by the Council to the Committee of 1851, by whom the previous application had been made. The Committee consisted of the Rev. Dr. Whewell, the Earl of Rosse, Sir John Herschel, and the Astronomer Royal. No report has yet been received by the Council of the Committee's consequent proceedings.

c. The recommendation, that "the Application made to Government in September 1852, concerning the great Southern Telescope, be renewed," was communicated by the Council to the President and Council of the Royal Society, by whom the steps were taken in 1852 to promote this important object, and a hope was expressed on the part of the Association that the President and Council of the Royal Society would renew their efforts to carry out an object of so much interest to astronomy. The Council have not been informed of any subsequent proceedings.

d. The General Committee having directed that "a Memorial should be presented to the Admiralty praying for the publication in a simple, uniform, and complete shape, tabular and descriptive, of the results of the trials of steam-ships employed in the public service," the Council referred to the President of the Section of Mechanical Science, with whom the request for this publication had originated, for the information required to enable the Council to proceed in drawing up the desired Memorial. The information was supplied, and a document, drawn up in more limited terms than the recommendation, and stating fully the data required and the purpose to which it was proposed to apply them, was transmitted to the Secretary of the Admiralty, who replied that the Lords Commissioners did not think it would be proper for them to give information in regard to vessels belonging to private companies. This reply was communicated to the President of the Mechanical Section and a Committee acting with him on the registration of ships' tonnage, by whom the subject will be again brought under the consideration of the Association at this Meeting.

e. The deputation appointed to wait on Her Majesty's Secretary for Foreign Affairs to "urge the desirableness of sending out an annual expedition to the Niger, as proposed by Dr. Baikie," have informed the Council that they have had an interview with Lord Clarendon, and have presented a Memorial which was very favourably received, and that the expedition has since been appointed, and has proceeded to the Niger under Dr. Baikie's direction.

II. At the Glasgow Meeting of the British Association, a Committee was appointed by the General Committee to consider a proposition which had been submitted to them for making a catalogue of the Philosophical Papers

contained in the various Scientific Transactions and Journals of all countries. The Report of this Committee was made at the Cheltenham Meeting, and was communicated by direction of the Council to the President and Council of the Royal Society, whose cooperation in this important undertaking was requested. The original Committee appointed by the Association, with the addition of two Members named by the Council of the Royal Society, were requested to give the subject a second and more full consideration. Their Report was presented to the Council of the Royal Society in June last, and was ordered to be printed and 250 copies to be sent to the British Association, for distribution amongst the Members of the General Committee at the Dublin Meeting, with a view to obtain the thorough concurrence and cooperation of the two Societies in the plan which shall be ultimately adopted for carrying out a work which promises to be of very considerable advantage to the cultivators of science in all countries.

III. The Council congratulate the General Committee on the publication which has taken place in the current year of the Meteorological Observations made by the Officers of the Irish Trigonometrical Survey at Mountjoy Barracks, near Dublin. It will be remembered that at the Southampton Meeting of the Association in the year 1846, a Committee was appointed to communicate with the Master-General of the Ordnance relative to the publication of these valuable observations, and that in January 1847, the Marquis of Anglesey, then holding the office of Master-General of the Ordnance, expressed to the Committee his readiness to meet the wishes of the British Association if the Treasury could be induced to grant the necessary funds, for which the Ordnance had not and could not make any provision. In consequence of this communication, the Council appointed a deputation to solicit from the Treasury that a grant for the purpose should be placed at the disposal of the Master-General, and were informed in reply, through the Secretary of the Ordnance, under date May 31, 1847, that the Treasury would be prepared to include the expense of the publication in the estimate to be laid before Parliament in 1848. The Council were also favoured with a letter from the Marquis of Anglesey, dated July 10, 1848, stating that "he had directed the publication of the Mountjoy Observations to be carried into effect with as little delay as possible." The publication having now taken place, it has appeared to the Council desirable that the part taken by the British Association in recommending and in procuring the funds for this valuable contribution to the Meteorology of the British Islands should be thus fully stated; because it has happened (no doubt accidentally) that no notice of any of these circumstances appears in the Preface or in the Introduction of the publication itself.

IV. The Council have been informed that circumstances will deprive the Dublin Meeting of the attendance of Edward J. Cooper, Esq., who was named as one of the Vice-Presidents for the Meeting; and with the concurrence of the Local Committee in Dublin, they recommend to the General Committee that the name of the Lord Chancellor of Ireland should be substituted for that of Mr. Cooper.

V. The Council have received letters of invitation to the Association to hold its Meeting in 1858 in Manchester, from—

The General Purposes' Committee of the City Council.
The Board of Directors of the Athenæum.
The Literary and Philosophical Society of Manchester.
The Botanical and Horticultural Society.
The Natural History Society.
The Photographic Society.

The Principal and Professors of Owens College.

VI. The Council has this day received letters of invitation to the Association to hold its Meeting in 1858 in Leeds, from—

The Mechanics' Institution and Literary Society.

The School of Practical Art.

VII. The Council have also this day been informed of an invitation to be presented from the Literary and Philosophical Society of Newcastle-on-Tyne and the Fine Arts Society of the North of England, to hold an early meeting at Newcastle.

VII. The General Committee will receive full information, in the subjoined Report from the Kew Committee, of the proceedings of that establishment during the past year; and the Council are persuaded that the General Committee will see with pleasure the evidences of the still increasing public utility of that institution, and of the credit thereby accruing to the British Association.

Report of the Kew Committee of the British Association for the Advancement of Science, for 1856–57.

Since the last Meeting of the British Association, the works necessary for lighting the Observatory with gas have been executed at a cost of £250, which has been defrayed by a Grant from the Wollaston Fund by the President and Council of the Royal Society.

Soon after the last Meeting of the Association, the Board of Works commenced the external repairs of the Observatory. These were completed in November last. The Chairman having represented to the Chief Commissioner of Works the necessity for considerable repairs to the interior of the Building, the Board of Works agreed to execute such repairs as soon as the necessary funds should be voted by Parliament. The Committee understand that the requisite vote has been passed, and that the works will be proceeded with in the course of the present summer.

The following memorandum relative to the re-establishment of self-recording magnetic instruments at the Kew Observatory was submitted to the Committee by General Sabine on July 22, 1856:—

"1. The decennial period in the solar magnetic variations, and its coincidence with a similar period in the frequency and amount of the solar spots, appear to be highly deserving of attention in an observatory established, as Kew is, for physical researches.

"2. There is reason to suppose that the permanency and regularity in the occurrence of the decennial period in the magnetic variations, and its coincidence with the periodic variation of the solar spots, might be effectually and satisfactorily tested by observations of both classes of phenomena at the alternate periods of maximum and minimum, say for example, in 1857 and 1858 as the anticipated period of maximum, and in 1863 and 1864 as the anticipated period of minimum, and so forth.

"3. The apparatus constructing under the superintendence of Mr. De la Rue will, it is hoped, fully meet the requirements of the research in respect to the solar spots.

"4. Since the time when the magnetic self-recording instruments belonging to the Kew Observatory were constructed under the direction of Mr. Ronalds, very considerable improvements have been made in the art of Photography, and the six months' trial which was made by Mr. Welsh of Mr. Ronalds' instruments, has led in several other respects to suggestions for improvements which could not but be expected to be required in instruments

of so novel a kind, while at the same time the six months' trial referred to has placed beyond doubt the sufficiency of a properly conducted research by means of self-recording instruments for the examination of the solar magnetic variations."

The Committee authorized Mr. Welsh to proceed with the construction of the instruments, which have now been completed at an expense not exceeding £250, this sum being defrayed from the funds supplied by the Government Grant through the Council of the Royal Society, the instruments remaining at Kew at the disposition of the Council of the Royal Society.

With the assistance of apparatus lent from General Sabine's department, the observatory is now possessed of the means of determining with great accuracy the various constants required in magnetic observation. Some alterations in the method of manipulation have, it is believed, added considerably to the accuracy of observation of the absolute value of the Magnetic Force.

At the request of the Foreign Office, Magnetical and Meteorological Instruments have been prepared at the Observatory for Mr. Lyons M'Leod, Consul at Mozambique. Mr. M'Leod attended on several occasions in order to make himself acquainted with their manipulation.

The following correspondence has taken place relative to an application from the Austrian Government to be supplied with Magnetical Instruments, to be employed in the scientific voyage undertaken by His Imperial Majesty's Frigate "Novara."

(Copy.)

"Admiralty, 31st December, 1856.

"DEAR GENERAL SABINE,—The Austrian Consul, Baron Rothschild, has written a pressing note to the Admiralty to ask where the enclosed list of instruments can be procured, and for any assistance we can give in ensuring their being the best. Will you be so good as to say what answer shall be sent? would it be too much to ask you to see that they are properly sent, and as nearly as you can, will you name the time the instruments could be ready?

"Yours faithfully,
(Signed) "JOHN WASHINGTON."

"*Memorandum of Instruments required by His Imperial Majesty's Frigate 'Novara.'*

"*a.* The Azimuth Compass.

"*b.* The Unifilar Magnetometer.

"*c.* Mr. Fox's apparatus for observing the magnetic force and inclination.

"*d.* Mr. Barrow's Circle for observing the magnetic inclination.

"To the apparatus *b* belongs also a peculiar apparatus for its erection and use on board ship.

"For the further use of these instruments and for taking the observations made thereby, it is desired that they may be delivered with the indication of their respective constants, as the moment of inertia, the temperature, coefficients, &c. &c.

"The Consulate-General will apply to the British Admiralty, who will, no doubt, kindly give the names of the makers who supply the British Admiralty, as it is desired that they be the same instruments as those on board Her Majesty's ships of war."

"London, 29th December, 1856."

(Copy.)

"13, Ashley Place, London,
January 7th, 1857.

"SIR,—I have received from Mr. James Yates a copy of the letter which you addressed to him on the 26th of last month, describing the scheme of the scientific voyage of circumnavigation about to be undertaken by His Imperial and Royal Majesty's Frigate 'Novara,' and requesting to be furnished with any suggestions which may assist you in carrying out the objects for which this voyage has been undertaken. I have deemed, therefore, that it may be agreeable to you to be informed, that in consequence of an application from Baron Rothschild to the British Admiralty, I have been requested to undertake, and have undertaken, to prepare the following instruments named in Baron Rothschild's letter for the magnetical observations to be made during the voyage, viz.—

"1. A Standard Azimuth Compass for the Declination.

"2. A Barrow's Inclinometer for the Inclination.

"3. A Fox's apparatus with Gimbal Stand for Inclination and Magnetic Force at sea.

"4. A Unifilar Magnetometer for observations of the Absolute Horizontal Magnetic Force on land.

"These instruments will be examined and their constants determined at the Kew Observatory of the British Association for the Advancement of Science, and will be ready by the end of February or beginning of March, together with instructions for the use of each of the instruments, and blank forms for the convenient record of the observations to be made with them. It is most desirable, however, that the physicist who is to be charged with the observations should have some previous practice with the instruments, and I would therefore beg leave to suggest that the gentleman who may be appointed to that duty should be directed to proceed in the first instance to London, so as to arrive there about the third week in February, and after having made himself familiar with the use of the instruments, should take them with him to Gibraltar, and there await the arrival of the 'Novara' on the passage from Trieste to Rio Janeiro.

"I have the honour to remain, Sir,
"Your obedient Servant,
(Signed) "EDWARD SABINE,
Major-General."

"P.S. Several of the instruments above mentioned will be ready by the end of the present month. Baron Rothschild's letter does not say anything about Marine Meteorological instruments. Should instruments of this description, such as are now furnished to the British Navy, be desired, they could be supplied by the Kew Observatory, and might accompany the magnetical instruments to Gibraltar."

"Dr. Karl Scherzer, Vienna."

The Magnetical Instruments for this Expedition have been prepared, and the Constants determined at the Observatory. Dr. Hochstätter, of Vienna, who has undertaken the superintendence of the Magnetical Observations to be made during the voyage, visited the Observatory in the end of February and beginning of March, to receive instructions in the use of the various instruments.

A letter has been received by General Sabine from the Archduke Ferdinand Maximilian, expressing his thanks, as Chief Officer of the Austrian

Navy, for the assistance afforded to Dr. Hochstätter, who writes that he had commenced his observations:—Dr. Hochstätter's letter is dated Gibraltar, 21st May, 1857.

In consequence of an application from the Hydrographer of the Admiralty, Dr. Baikie and Lieut. Glover, who have recently sailed on an expedition to Africa, were furnished with Magnetical Instruments, whose Constants had been previously determined at the Observatory. Dr. Baikie and Lieut. Glover visited the Observatory, when detailed instructions were communicated to them by Mr. Welsh, as to the practical use of the instruments.

Application having been made to the Royal Society by Her Majesty's Secretary of State for the Colonies, relative to a supply of Magnetical Instruments for an expedition to British North America, under the direction of Mr. Palliser, Lieut. Blakiston, R.A., who accompanies the Expedition, attended for some time at the Observatory for the purpose of manipulating with the Magnetical Instruments, which have been prepared under the direction of Mr. Welsh for the use of the Expedition. The Constants of these instruments were determined as in the other instances already referred to in this Report.

At the request of the Council of the Royal Society, Mr. Welsh has prepared the Magnetical Instruments required in the North Polar Expedition, which has been fitted out at the expense of Lady Franklin: the cost of preparation of these instruments is defrayed by the Royal Society. The instruments themselves have been supplied from Major-General Sabine's establishment at Woolwich.

General Sabine having communicated to the Committee that £200 had been placed at his disposal by the Admiralty, for the purpose of conducting the Magnetical Survey of Scotland, in connexion with the general Magnetic Survey of the British Islands, as recommended at the last Meeting of the Association, the Committee have arranged that Mr. Welsh shall undertake such survey in the course of the present and following summer.

Sir James Clark Ross has already commenced the Survey of England, taking Kew as his base station.

A new method, proposed by Dr. Lloyd, of determining the absolute total magnetic force by means of the Dip Circle, will be employed in this Survey. Dip Circles adapted for this method have been supplied to Sir James C. Ross and Mr. Welsh, also to Lieut. Blakiston for his Survey in North America.

Photoheliograph.

On the 20th of May, 1854, Benj. Oliveira, Esq., F.R.S., placed the sum of £50 at the disposal of the Council of the Royal Society, to be appropriated during that year in any manner the Council might consider most in harmony with the interests of Science. Mr. Oliveira further stated, that he might probably in future years offer a similar sum if the mode of its disposal appeared to him eligible; and an application having at the same time been made by the Kew Committee for the sum of £150, in order to erect a Photographic Apparatus for registering the position of the spots in the Sun's disc, as suggested by Sir John Herschel, the Council of the Royal Society devoted to this purpose the donation of Mr. Oliveira, and proposes, should it be continued, to apply it for the next two years in replacement of the sum of £100 which the Council in the mean time advanced from the Donation Fund of the Royal Society, in order that the undertaking might not be delayed. This arrangement was approved by Mr. Oliveira, and the apparatus has, under the direction of Warren De la Rue, Esq., F.R.S., been completed by Mr. Ross at the cost of about £180.

The object-glass of this instrument is $3\frac{4}{10}$ inches aperture and 50 inches focal length; it is not corrected for achromatism in the ordinary manner, but so as to produce a coincidence of the visual and photogenic foci. The secondary objectives for magnifying the image produced by the principal object-glass are of the Huyghenian form. They are three in number, producing respectively images of the sun 3, 4, and 8 inches in diameter. Between the two lenses of each of these secondary object-glasses is inserted a diaphragm-plate carrying the fixed micrometer wires, which are of platinum; these wires are four in number, two at right angles to the other two. One of the wires of each pair is in such a position that they may both be made tangential to the sun's image, while the other two cross at a point situated near the sun's centre. By means of these wires, the distance in arc between each pair having been once for all ascertained astronomically for each secondary object-glass, it will be easy to determine all the data necessary for ascertaining the relative magnitudes and positions of the sun's spots. These micrometer wires are under the influence of springs, so as to preserve a tension upon them when expanded by the sun's heat, and thus to keep them straight.

The principal and secondary object-glasses are not mounted in an ordinary cylindrical tube, but in a pyramidal trunk square in section, 5 inches in the side at the upper end, which carries the principal object-glass, and 12 inches in the side at the lower end, which carries the photographic plate-holder and the usual ground glass screen for focusing.

This trunk is firmly supported by a declination axis of hard gun-metal $2\frac{1}{2}$ inches in diameter; it is furnished with a declination circle 10 inches in diameter, reading to one minute of arc, and has a clamp and screw motion for fine adjustment in declination.

The declination axis works in Y-bearings at the top of the polar axis, which is 12 inches long; it is 4 inches diameter at its upper end and $1\frac{1}{2}$ inch at its lower end. The lower end fits with a slight taper into a brass collar up to a shoulder, the friction being reduced by a steel spring plate pressing against a hardened steel hemisphere at the end of the axis.

It will be seen by the above description, that every precaution has been taken to secure stiffness in the telescope combined with freedom in the motion of the polar axis. The polar axis is driven by a clock driver, which answers perfectly, and is easy of regulation to the greatest nicety, so that the sun's limb remains for a long period in contact with the tangential wires. Near the lower end of the polar axis is fixed the hour-circle, which, like the declination circle, is 10 inches in diameter; it is graduated to read to 2 seconds of time. An endless screw, making about two revolutions in one minute, geers into the hour-circle and connects it with the clock. As it is generally necessary to make small corrections in right ascension after the tangent screw has been geered with the driving clock, in order to bring the sun's image in position with respect to the micrometer wires, a sliding plate is provided which carries the bearings of the tangent screw; this is acted upon by a second fine screw parallel with the tangent screw; so that by rotating the second screw, the sliding plate and the tangent screw are moved through a small space, and the hour-circle thus caused to rotate to the extent necessary for bringing the sun's image in position.

The clock is driven by two weights, one pulling upwards over a pulley, the other downwards, thus suspending the barrel and equalizing the pull and avoiding friction on its bearings. By causing the click of the winding lever to abut on the ratchet-wheel of the going part of the clock during the period of winding, the clock goes at its normal speed while it is being wound.

The mode of regulating the clock is extremely simple and efficacious; it is

effected by approaching to, or withdrawing from, a hollow cone over a small wheel, on which are attached, by means of flat springs, two small weights, which expand by centrifugal force and come in contact with the inside of the hollow cone.

The polar axis of the telescope is carried by a dial-plate, which fits on the top of a hollow column of cast iron, the section of which is a parallelogram. This column is securely fastened to the stone foundation. The instrument is mounted within the rotating dome of the Kew Observatory, which has been repaired and put in order for that purpose. The photographic dark room is at present too distant from the telescope, but it is contemplated to construct one close to it, as serious inconvenience has been already experienced in the preliminary experiments in consequence thereof.

The telescope and its mechanical appliances may be said to be perfect so far as they go, but experience will undoubtedly suggest several minor alterations and additions before the telescope is brought practically to work. The photographing of such minute objects as the sun's spots will require at all times the utmost skill and care of an accomplished photographer, even when the telescope has been fairly started. The difficulties yet to be mastered must occupy some considerable time. The first attempts have been confined to the production of negative photographs, but in consequence of the imperfections always existing in the collodion film, it has been deemed advisable to make attempts to produce positive pictures, and recourse may ultimately have to be made to the Daguerreotype process.

The verification of Meteorological Instruments has been continued on the same plan as in previous years. The following are the numbers of instruments which have been verified since the last meeting of the Association:—

	Barometers.	Thermometers.	Hydrometers.
For the Admiralty	127	840	605
For the Board of Trade	86	360	140
For Opticians and others	65	324	6
Total	278	1524	751

Mr. Stewart having left the Observatory, as mentioned in the last Annual Report, the Committee in October last engaged Mr. Charles Chambers of Leeds, on the recommendation of the Council of the Society of Arts. The Committee report very favourably of the intelligence and assiduity with which he has discharged his duties.

JOHN P. GASSIOT,
Chairman.

Accounts of the Kew Committee of the British Association from Aug. 6, 1856, *to Aug.* 26, 1857.

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance from last account				260	4	6
Received from the General Treasurer				350	0	0
,, for the verification of Instruments—						
from the Board of Trade	52	10	0			
from the Admiralty	66	15	0			
from Opticians and others	22	0	0			
				141	5	0
				£751	9	6

PAYMENTS.

	£	s.	d.	£	s.	d.
Salaries, &c.:—						
To Mr. Welsh, one year, ending Aug. 27	200	0	0			
Ditto, allowed for petty travelling expenses	10	0	0			
Mr. J. V. Magrath, one year, ending Aug. 14	50	0	0			
Mr. C. Chambers, three quarters, ending July 6	37	10	0			
Mr. Beckley, 55 weeks, ending Aug. 24	96	5	0			
Mr. Stewart, Sept. 1—15, 1856	3	10	0			
				397	5	0
Apparatus, Materials, Tools, &c.				28	10	7
Plumber's and Bricklayer's work				33	11	2
Stoves, Ironmongery and Carpentry				32	18	2
Printing, Stationery, Books, Postage				24	9	8
Coals and Gas				19	0	2
House Expenses, Chandlery, &c.				17	10	4
Porterage and petty expenses				5	19	3
Rent of Land, one year ending Oct. 10, 1857				21	0	0
Balance in hand				171	5	2
				£751	9	6

I have examined the above account and compared it with the vouchers presented to me, and find the Balance to be One Hundred and Seventy One Pounds Five Shillings and Twopence.

17*th July*, 1857.

R. HUTTON.

Report of the Parliamentary Committee to the Meeting of the British Association at Dublin, in August 1857.

The Parliamentary Committee have the honour to report as follows:—

The question discussed in the Report of your Committee, addressed to the Meeting held at Glasgow in 1855, viz. "Whether any measures could be adopted by the Government or Parliament that would improve the position of Science and its cultivators," has been much considered by the Council of the Royal Society. They assembled for this purpose in the autumn of last year, and were then assisted in their deliberations by the replies received to the circular of the 20th August last, agreed upon at Cheltenham, and issued to all Members of the General Committee.

Of these replies an able digest has been prepared by Professor Phillips, who was also a Member of the Sub-Committee appointed on behalf of the Royal Society to consider this important subject.

The Council of the Royal Society, at their meeting held on the 15th of January last, passed twelve Resolutions, which may be considered as embodying their reply to the question above stated, and your Committee are gratified by observing that most of the recommendations adopted in the Glasgow Report have, in substance, received the sanction of the official representatives of the most ancient and venerable of our Scientific Institutions. At that meeting of the Council a resolution was passed, that the President be authorized to communicate the twelve Resolutions to your Committee, with a request that the same might obtain such support from our Members as they might consider them entitled to receive. The Council of the Royal Society likewise resolved that a copy of their Resolutions should be forwarded to Lord Palmerston by their President, who by letter, bearing date the 28th of January, transmitted the same accordingly.

The consideration of the steps proper to be taken in pursuance of the above request addressed to your Committee, formed the chief subject of our deliberations during the current year. We determined that it was not expedient at present to take any steps beyond moving for the production of the letter of the President of the Royal Society of the 28th of January abovementioned, with the copy of the twelve Resolutions enclosed therein; and this has been done accordingly, in the House of Lords by Lord Burlington, and in the House of Commons by Mr. Robert Stephenson.

We were much influenced in this determination by the consideration of the peculiar circumstances under which Parliament met, which have much abridged the time at their disposal for the discussion of any measures of importance, and by the further consideration that it might not be expedient to precipitate a decision on matters which were new to the general public.

Again, though the Resolutions in question have received the general approval of your Council, at a meeting held on the 16th January last, we thought it right that the Committee of Recommendations should have an opportunity of expressing their opinion upon them before any steps were taken to urge their adoption on the Government or Parliament.

By the retirement of Mr. Heywood from Parliament, your Committee have been deprived of the services of one of the most zealous of their members. Mr. Heywood was not only most constant in his attendance, but no one had the objects for which your Committee was constituted more sincerely at heart.

The Duke of Argyll and the Earl of Rosse must, in pursuance of the resolution adopted at Liverpool in 1854, be deemed to have vacated their seats in your Committee, but we recommend that they should be re-elected.

Your Committee also recommend that the two vacancies caused by the retirement from Parliament of Sir Charles Lemon, Bart., and Mr. Heywood, be filled by the election of the Right Honourable Joseph Napier, M.P. for the University of Dublin, and Edward Cooper, Esq., F.R.S., of Markree Castle, M.P. for the County of Sligo.

We have also to report the loss of the services of Mr. John Ball. His scientific knowledge and zeal in the cause rendered him a valuable Member of your Committee. This vacancy still remains to be supplied by the General Committee.

14th August, 1857. WROTTESLEY, *Chairman.*

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE DUBLIN MEETING IN AUGUST AND SEPTEMBER 1857.

[When Committees are appointed, the Member first named is regarded as the Secretary of the Committee, except there be a specific nomination.]

Involving Grants of Money.

That the sum of £500 be placed at the disposal of the Council for the maintaining the Establishment and providing for the continuance of Special Researches at Kew Observatory.

That Professor Maskelyne, Mr. Hardwich, Mr. Llewellyn, and Mr. Hadow, be a Committee to report on Researches on the Chemistry of Photography; with £10 at their disposal.

That Dr. A. Voelcker be requested to make Researches and Experiments on the Constituents of Manures; with £25 at his disposal for the purpose.

That Professor Sullivan be requested to make Experiments on the Solubility of Salts at temperatures above 100° Cent., and on the mutual action of Salts in Solution; with £20 at his disposal for the purpose.

That Mr. Robert Mallet, C.E., be requested to continue his Experiments on Earthquake Waves; with £50 at his disposal for the purpose.

That Mr. E. P. Wright, Professor Melville, and Professor Kinahan, be a Committee to report on the Dredging of the Coast of Ireland; with £10 at their disposal for the purpose.

That Mr. W. Keddie and Mr. Connal be requested to report on the Vegetable Imports of Scotland; with £10 at their disposal for the purpose.

That Professor Henslow, Professor Phillips, Sir W. Jardine, Mr. C. C. Babington, Professor Balfour, Professor Owen, Dr. Hooker, Mr. J. S. Bowerbank, Rev. M. J. Berkeley, Professor Huxley, and Dr. Lankester, be a Committee to report on Typical Forms for Museums; with £10 at their disposal for the purpose.

That the Rev. C. P. Miles, Professor Balfour, Dr. Greville, and Mr. C. Eyton, be a Committee to report on the Dredging of the West Coast of Scotland; with £25 at their disposal for the purpose.

That Professor Bell, Dr. Williams, and Dr. Lankester, be a Committee for the purpose of completing a Report on the British Annelida; with £25 at their disposal.

That Dr. Daubeny be requested to conclude the Experiments on the Growth and Vitality of Seeds; with £5 5*s.* at his disposal for the purpose.

That Dr. Daubeny, Mr. C. C. Babington, Professor Buckman, and Dr. Voelcker, be a Committee to report on Researches on the Growth of Plants; with £10 at their disposal.

That Professor Kinahan, Mr. E. P. Wright, Mr. J. R. Green, and Dr. Carte, be a Committee to report on the Dredging in the Dublin district; with £10 at their disposal.

That Mr. R. Patterson, Professor Dickie, Professor W. Thomson, and Mr. Hyndman, be a Committee to report on the Dredging on the North Coast of Ireland; with £20 at their disposal.

That Mr. G. Rennie, C.E., be requested to continue his Experiments on the production of Heat by motion in Fluids; with £20 at his disposal for the purpose.

That Mr. James Thomson, C.E., be requested to continue his Experiments on the Measurement of the Discharge of Water; with £10 at his disposal for the purpose.

Involving Applications to Government or Public Institutions.

Resolved,—That it is of great importance to the progress of Science that the Magnetic Observations which have already added so much to our knowledge of terrestrial magnetism, should be continued. That the influence of the Association will be well employed in attaining this object, and that it is desirable to obtain the cooperation of the Royal Society. That a Committee be appointed, consisting of the President, the Rev. Dr. Robinson, and Major-General Sabine, to request, on the part of the British Association, the co-operation of the President and Council of the Royal Society, and to take in conjunction with them such steps as may appear necessary, including, if it be thought desirable, an application to Government.

That Lord Wrottesley, Dr. Robinson, Mr. Osler, General Sabine, Mr. Welsh, Sir W. S. Harris, and Dr. Whewell, be appointed a Committee to express to the Board of Trade the wish of the British Association that self-recording Anemometrical Instruments should be established on some of the islands in the Atlantic Ocean, in aid of the Meteorological Observations now being carried on on ship-board under the direction of the Meteorological department of the Board of Trade.

That application be made to Her Majesty's Government to send a vessel to examine and survey the entrance to the Zambesi River in South Africa, and to ascend the river as far as may be practicable for navigation. That the following Gentlemen be appointed a deputation to make the application:—The President, Sir R. I. Murchison, Sir H. Rawlinson, General Sabine, Mr. Macgregor Laird.

That the President, the Lord Wrottesley, the Right Honourable J. Napier, Dr. Robinson, and Major-General Sabine, be a Committee for the purpose of making application to the Government to send a vessel to the vicinity of Mackenzie River, to make a series of magnetic observations, with special reference to the determination of the laws now known to rule the magnetic storms.

It having been found that the application of science to the improvement of Steam-ships has been impeded by the difficulty of obtaining the necessary data from the present registration,—Resolved—That a Committee be appointed and authorized to communicate, if necessary, with the Board of Trade on the subject;—the Committee to consist of Admiral Moorsom, Mr. J. Scott Russell, Mr. J. E. M'Connell, Mr. Charles Atherton, Mr. William Fairbairn, Mr. J. Perry, Mr. Henry Wright, Mr. Henderson.

Applications for Reports and Researches.

That Dr. Odling be requested to prepare a Report on the recent progress of Organic Chemistry.

That Professor Haughton and Mr. David Forbes, F.G.S., be requested to furnish a Report on the state of our knowledge of the Mineralogical and Chemical composition of Rocks of an Igneous origin.

That Professor Oldham be requested to prepare a Report on the state of our knowledge of the Geology of India.

That Mr. A. H. Haliday, Professor Kinahan, and Mr. Wright, be requested to prepare a Supplement to the Fauna of Ireland, comprising the additions made thereto since the Report of the late Mr. William Thompson.

That Mr. W. Andrews be requested to report on the Species of Fishes which occur on the West Coast of Ireland.

That Mr. J. R. Green be requested to report on the present state of our knowledge of the Discoid Medusidæ of the British Seas.

That Professor Kinahan be requested to prepare a Report on the Crustacea of Dublin Bay.

That Mr. Oldham be requested to continue his researches on Steam-Navigation at Hull.

Communications to be printed entire among the Reports.

Gustaf Plarr.—On some Transformations of a Series of Factorial Exponentials.

Herren Schlagintweit.—On some Physical Observations made in India.

Mr. Commissioner Hargreaves.—On the Algebraic Couple.

Mr. A. Grubb.—On the Improvement of the Reflecting Telescope and the Equatorial Mounting.

Mr. Oldham.—On Steam-Navigation at Hull.

Mr. C. Vignoles.—On Suspension Bridges.

Mr. P. Barlow.—On Suspension Bridges.

Synopsis of Grants of Money appropriated to Scientific Objects by the General Committee at the Dublin Meeting in August and September 1857, with the name of the Member, who alone, or as the First of a Committee, is entitled to draw for the Money.

	£	s.	d.
Kew Observatory.			
At the disposal of the Council for defraying expenses	500	0	0
Chemical Science.			
Maskelyne, Prof.—Chemistry of Photography	10	0	0
Voelcker, Prof.—On Constituents of Manures............	25	0	0
Sullivan, Prof.—Solubility of Salts	20	0	0
Geology.			
Mallet, R., C.E.—Earthquake Wave Experiments	50	0	0
Zoology and Botany.			
Wright, E. P.—Dredging Coast of Ireland	10	0	0
Keddie, W.—Vegetable Imports of Scotland..............	10	0	0
Henslow, Prof.—Typical Forms for Museums	10	0	0
Miles, Rev. C. P.—Dredging West Coast of Scotland......	25	0	0
Bell, Prof.—Report on Annelida	25	0	0
Daubeny, Dr.—Experiments on Vitality of Seeds..........	5	5	0
Daubeny, Dr.—Growth of Plants	10	0	0
Kinahan, Prof.—Dredging near Dublin	10	0	0
Patterson, R.—Dredging North Coast of Ireland	20	0	0
Mechanical Science.			
Rennie, G.—Production of Heat in Fluids	20	0	0
Thomson, J.—Discharge of Water......................	10	0	0
Grants......	£760	5	0

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	3
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phænomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument, 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1839	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1839	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phænomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0

	£	s.	d.
Periodical Phænomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phænomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phænomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phænomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Asso-

ciation expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, John Taylor, Esq., 6 Queen Street Place, Upper Thames Street, London, for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the Members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include, as a part of the amount, the specified balance which may remain unpaid on the former grant for the same object.

General Meetings.

On Wednesday, Aug. 26, at $8\frac{1}{2}$ P.M., in the Rotunda, C. G. B. Daubeny, M.D., F.R.S., Professor of Botany in the University of Oxford, resigned the office of President to the Rev. Humphrey Lloyd, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A., who took the Chair and delivered an Address, for which see page xlvii.

On Thursday Evening the Association was received by the Royal Dublin Society.

On Friday, Aug. 28, at $8\frac{1}{2}$ P.M., in the Rooms of the Royal Dublin Society, Prof. W. Thomson, F.R.S., delivered a Discourse on the Atlantic Telegraph.

On Saturday, Aug. 29, at $8\frac{1}{2}$ P.M., the Association was received by the Royal Irish Academy.

On Monday, Aug. 31, at $8\frac{1}{2}$ P.M., in the Rooms of the Royal Dublin Society, the Rev. Dr. Livingstone, D.C.L., delivered a Discourse on his recent discoveries in Africa.

On Tuesday, Sept. 1, at $8\frac{1}{2}$ P.M., the Association was received in the Castle by His Excellency the Lord Lieutenant of Ireland.

On Wednesday, Sept. 2, at 3 P.M., the concluding General Meeting took place in Trinity College, when the Proceedings of the General Committee, and the Grants of Money for scientific purposes, were explained to the Members.

The Meeting was then adjourned to Leeds*.

* The Meeting is appointed to take place on Wednesday, the 22nd of September, 1858.

ADDRESS

BY

The Rev. HUMPHREY LLOYD, D.D., D.C.L.,

F.R.S.L. & E., V.P.R.I.A., Fellow of Trinity College, Dublin.

Gentlemen of the British Association,

Before I proceed to the task which devolves upon me this evening, in virtue of the position in which your kindness has placed me, suffer me first to thank you for the high honour you have conferred. But, highly as I esteem the distinction, it was not without hesitation that I accepted it; for no one can feel more strongly than I do myself how unfit I am for some of the duties connected with it, or how much more adequately they might have been performed by others. But I knew, at the same time, that it has been the desire of your Council, when practicable, to select your President from among those local Members who had served in the ranks of the Association and had shared in its labours; and with such knowledge, and the consciousness that I had, at least, that humble claim, I felt that I had no right to dispute your choice.

I do not know whether I may venture to interpret further your motives, and to assign another reason for your selection. Two-and-twenty years have elapsed since you visited this city. Upon that occasion my nearest relative presided, and I myself had the honour of serving as one of your local Secretaries. Many concurring circumstances contributed to make that meeting an agreeable one; and if your Council has thought fit, on this occasion, to associate the present with the memories of the past, the motive is, at least, a pardonable one.

Gentlemen, this is to me a solemn occasion. Two-and-twenty years are no inconsiderable portion even of the longest life; and that man's moral nature is not to be envied, who can contemplate the distant past thus vividly recalled without emotion. These two decades have brought with them their own large measure of change. The Body in which we are associated has

grown up from youth to maturity; many of its honoured names are now sought for only in the imperishable records of their toils; the institutions which welcomed it here upon its former visit to this city have all received the impress of the changing times. And yet, amid all this change, we meet once more in the same city,—in the same room,—to enter again on the same labours; our assemblage is now, as it was before, dignified by the presence of the Representative of Majesty; and I see around me, associated for this task, many of those who shared it before;—the men whose sagacity first perceived the want of such a Society as this, whose energy supplied it, and whose wisdom directed its steps while it had need of guidance.

I trust I may be forgiven for dwelling thus far on the peculiar circumstances under which we are here assembled; and I now hasten to discharge the task which the usages of this Chair impose upon me, and proceed to lay before you, as well as I am able, a brief sketch of the recent progress of some of those Sciences to whose advancement we are pledged by our institution. In doing so, I gladly follow the practice which has of late become the rule, namely, that your President for each year should bring under your notice chiefly, the recent additions to those departments of Science with which he happens to be himself most familiar. It is plainly fitting that he who addresses you should speak, as far as he can, from his own acquired knowledge. Partial views are better than inexact ones; and provision is made for their completion in the annual change of your Officer. In the present instance I derive the full advantage of this arrangement, inasmuch as the subjects upon which I could not thus speak have been, most of them, ably treated by my predecessor in this Chair.

To commence, then, with *Astronomy*:—The career of planetary discovery, which began in the first years of the present century, and was resumed in 1845, has since continued with unabated ardour. Since 1846 not a single year has passed without some one or more additions to the number of the planetoids; and in one year alone (1852), no fewer than *eight* of these bodies were discovered. The last year has furnished its quota of five; and in the present *three* more have been found, one by Mr. Pogson of Oxford, and the other two by M. Goldschmidt of Paris. Their known number is now forty-five. Their total mass, however, is very small; the diameter of the largest being less than forty miles, while that of the smallest, *Atalanta*, is little more than four.

These discoveries have been facilitated by star-maps and star-catalogues, the formation of which they have, on the other hand, stimulated. Two very extensive works of this kind are now in progress,—the Star-catalogue of M. Chacornac, made at the Observatory of Marseilles, in course of publication by the French Government, and that of Mr. Cooper, made at his Observatory at Markree, in Ireland, which is now being published by the help of the parliamentary grant of the Royal Society. It is a remarkable result of the

latter labour, that no fewer than seventy-seven stars, previously catalogued, are now missing. This, no doubt, is to be ascribed, in part, to the errors of former observations; but it seems reasonable to suppose that, to some extent at least, it is the result of changes actually in progress in the Sidereal Systems.

The sudden appearance of a new fixed star in the heavens,—its subsequent change of lustre,—and its final disappearance, are phenomena which have at all times attracted the attention of astronomers. About twenty such have been observed. Arago has given the history of the most remarkable, and discussed the various hypotheses which have been proposed for their explanation. Of these, the most plausible is that which attributes the phenomenon to unequal brightness of the faces of the star, which are presented successively to the earth by the star's rotation round its axis. On this hypothesis the appearance should be *periodic*. M. Goldschmidt has recently given support to this explanation, by rendering it probable that the new star of 1609 is the same whose appearance was recorded in the years 393, 798, and 1203; its period, in such case, is $405\frac{1}{2}$ years.

The greater part of the celestial phenomena are comprised in the movements of the heavenly bodies, and the configurations depending on them; and they are for the most part reducible to the same law of gravity which governs the planetary motions. But there are appearances which indicate the operation of other forces, and which therefore demand the attention of the physicist,—although, from their nature, they must probably long remain subjects of speculation. Of these the spiriform nebulæ, discovered by Lord Rosse, have been already referred to from this Chair, as indicating changes in the more distant regions of the universe, to which there is nothing entirely analogous in our own System. These appearances are accounted for, by an able anonymous writer, by the action of gravitating forces combined with the effects of a resisting medium,—the resistance being supposed to bear a sensible proportion to the gravitating action.

The constitution of the central body of our own System presents a nearer and more interesting subject of speculation. Towards the close of the last century many hypotheses were advanced regarding the nature and constitution of the Sun, all of which agreed in considering it to be an opaque body, surrounded at some distance by a luminous envelope. But the only certain fact which has been added to science in this department is the proof given by Arago, that the light of the Sun emanated, not from an incandescent solid, but from a gaseous atmosphere; the light of incandescent solid bodies being *polarized by refraction*, while the light of the Sun, and that emitted by gaseous bodies, is *unpolarized*.

According to the observations of Schwabe, which have been continued without intermission for more than thirty years, the magnitude of the solar surface obscured by spots increases and decreases *periodically*, the length of the period being 11 years and 40 days. This remarkable fact, and the relation which it appears to bear to certain phenomena of terrestrial magnetism,

have attracted fresh interest to the study of the solar surface; and, upon the suggestion of Sir John Herschel, a photo-heliographic apparatus has lately been established at Kew, for the purpose of depicting the actual macular state of the Sun's surface from time to time.

It is well known that Sir William Herschel accounted for the solar spots by currents of an elastic fluid, ascending from the body of the Sun, and penetrating the exterior luminous envelope. A somewhat different speculation of the same kind has been recently advanced by Mosotti, who has endeavoured to connect the phenomena of the solar spots with those of the *red protuberances*, which appear to issue from the body of the Sun in a total eclipse, and which so much interested astronomers in the remarkable eclipse of 1842.

Next to the Sun, our own satellite has always claimed the attention of astronomers, while the comparative smallness of its distance inspired the hope that some knowledge of its physical structure could be attained with the large instrumental means now available. Accordingly, at the Meeting of the Association held at Belfast in 1852, it was proposed that the Earl of Rosse, Dr. Robinson, and Professor Phillips be requested to draw up a Report on the physical character of the Moon's surface, as compared with that of the Earth. That the attention of these eminent observers has been directed to the subject, may be inferred from the communication since made by Professor Phillips to the Royal Society on the lunar mountain, Gassendi, and the surrounding region; but I am not aware that the subject is yet ripe for a Report.

I need not remind you, that the Moon possesses neither *sea* nor *atmosphere* of appreciable extent. Still, as a negative, in such case, is relative only to the capabilities of the instruments employed, the search for the indications of a *lunar atmosphere* has been renewed with every fresh augmentation of telescopic power. Of such indications the most delicate, perhaps, are those afforded by the occultation of a planet by the Moon. The occultation of Jupiter, which took place on the 2nd of January last, was observed with this reference, and is said to have exhibited no *hesitation*, or change of form or brightness, such as would be produced by the refraction or absorption of an atmosphere. As respects the *sea*, the mode of examination long since suggested by Sir David Brewster is probably the most effective. If water existed on the Moon's surface, the Sun's light reflected from it should be completely polarized at a certain elongation of the Moon from the Sun. No traces of such light have been observed; but I am not aware that the observations have been repeated recently with any of the larger telescopes.

It is now well understood that the path of astronomical discovery is obstructed much more by the Earth's atmosphere, than by the limitation of telescopic powers. Impressed with this conviction, the Association has, for some time past, urged upon Her Majesty's Government the scientific import-

ance of establishing a large reflector at some elevated station in the Southern Hemisphere. In the meantime, and to gain (as it were) a sample of the results which might be expected from a more systematic search, Professor Piazzi Smyth undertook, last summer, the task of transporting a large collection of instruments—meteorological and magnetical, as well as astronomical—to a high point on the Peak of Teneriffe. His stations were two in number, at the altitudes above the sea of 8840 and 10,700 feet respectively; and the astronomical advantages gained may be inferred from the fact, that the heat radiated from the Moon, which has been so often sought for in vain in a lower region, was distinctly perceptible with the aid of the thermo-multiplier.

The researches relative to the *Figure of the Earth*, and the *Tides*, are intimately connected with Astronomy, and next claim our attention.

The results of the Ordnance Survey of Britain, so far as they relate to the Earth's figure and mean density, have been lately laid before the Royal Society by Colonel James, the Superintendent of the Survey. The ellipticity deduced is $\frac{1}{299 \cdot 33}$. The mean specific gravity of the Earth, as obtained from the attraction of Arthur's Seat, near Edinburgh, is 5·316,—a result which accords satisfactorily with the mean of the results obtained by the torsion balance. Of the accuracy of this important work it is sufficient to observe, that when the length of each of the measured bases—in Salisbury Plain, and on the shores of Lough Foyle—was computed from the other, through the whole series of intermediate triangles, the difference from the measured length was only 5 inches in a length of from 5 to 7 miles.

Our knowledge of the laws of the *Tides* has received an important accession, in the results of the Tidal Observations made around the Irish coasts in 1851, under the direction of the Royal Irish Academy. The discussion of these observations was undertaken by Professor Haughton, and that portion of it which relates to the diurnal tides has been already completed and published. The most important result of this discussion is the separation of the effects of the Sun and the Moon in the diurnal tide,—a problem which was proposed by the Academy, as one of the objects to be attained by the contemplated observations, and which has been now for the first time solved. From the comparison of these effects Professor Haughton has drawn some remarkable conclusions relative to the *mean depth of the sea* in the Atlantic. In the dynamical theory of the tides, the ratio of the solar to the lunar effect depends not only on the masses, distances, and periodic times of the two luminaries, but also on the depth of the sea; and this, accordingly, may be computed when the other quantities are known. In this manner Professor Haughton has deduced, from the solar and lunar coefficients of the diurnal tide, a mean depth of 5·12 miles,—a result which accords in a remarkable manner with that inferred from the ratio of the semidiurnal coefficients, as obtained by Laplace from the Brest observations. The subject, however, is far from being exhausted. The depth of the sea, deduced from the solar

and lunar *tidal intervals*, and from *the age* of the lunar diurnal tide, is somewhat more than double of the foregoing; and the consistency of the individual results is such as to indicate, that their wide difference from the former is not attributable to errors of observation. Professor Haughton throws out the conjecture that the depth, deduced from the tidal *intervals* and *ages*, corresponds to a different part of the ocean from that inferred from the *heights*.

The phenomena of *Terrestrial Magnetism* present many close analogies with those of the tides; and their study has been, in a peculiar manner, connected with the labours of this Association. To this body, and by the hands of its present General Secretary, were presented those Reports on the distribution of the Terrestrial Magnetic Force which reawakened the attention of the scientific world to the subject. It was in the Committee-rooms of this Association that the first step was taken towards that great magnetic organization which has borne so much fruit;—it was here that the philosophical sagacity of Herschel guided its earlier career;—and it was here again that the cultivators of the science assembled, from every part of Europe, to deliberate about its future progress. It was natural, therefore, that the results obtained from such beginnings should form a prominent topic in the addresses which have been annually delivered from this Chair; and the same circumstances will plead my excuse, if I now revert to some of them which have been already touched upon by my predecessors.

It has been long known that the elements of the Earth's magnetic force were subject to certain regular and recurring changes, whose periods were, respectively, a *day* and a *year*, and which, therefore, were referred to the Sun as their source. To these periodical changes Dr. Lamont, of Munich, added another of *ten years*, the diurnal range of the magnetic declination having been found to pass from a maximum to a minimum, and back again, in about that time.

But besides these slow and regular changes, there are others of a different class, which recur at *irregular* intervals, and which are characterized by a large deviation of the magnetic elements from their normal state, and generally also by rapid fluctuation and change. These phenomena, called by Humboldt "magnetic storms," have been observed to occur *simultaneously* in the most distant parts of the earth, and therefore indicate the operation of causes affecting the entire globe. But, casual as they seem, they are found to be subject to laws of their own. Professor Kreil was the first to discover that, at a given place, they recurred more frequently at certain hours of the day than at others; and that consequently, in their *mean effects*, they were subject to *periodical* laws, depending upon the *hour* at each station.

The laws of this periodicity have been ably worked out by General Sabine, in his discussion of the results of the British Colonial Observatories; and he has added the important facts, that the same phenomena observe also the two other periods already noticed, namely the *annual* and the *decennial* periods. He has further arrived at the very remarkable result, that the de-

cennial magnetic period coincides, both in its duration and in its epochs of maxima and minima, with the decennial period observed by Schwabe in the solar spots; from which it is to be inferred that the Sun exercises a magnetic influence upon the Earth, dependent on the condition of its luminous envelope.

We are thus in the presence of two facts, which appear at first sight opposed, namely, the *absolute simultaneity* of magnetic disturbances at all parts of the Earth, and their *predominance at certain local hours* at each place. General Sabine accounts for this apparent discrepancy by the circumstance, that the hours of maximum disturbance are different for the different elements; so that there may be an abnormal condition of the magnetic force, operating at the same instant over the whole globe, but manifesting itself at one place chiefly in one element, and at another place in another. I would venture to suggest, as a subject of inquiry, whether the phenomena which have been hitherto grouped together as "occasional" effects, may not possibly include two distinct classes of changes, obeying separate laws—one of them being strictly *periodic*, and constituting a part of the regular diurnal change, while the other is strictly *abnormal*, and *simultaneous*. If this be so, it would follow that we are not justified in separating the larger changes from the rest, merely on the ground of their magnitude; and that a different analysis of the phenomenon will be required.

The effects hitherto considered are all referable to the Sun as their cause. Professor Kreil discovered, however, that another body of our System—namely, our own satellite—exerted an effect upon the magnetic needle; and that the magnetic declination underwent a small and very regular variation, whose amount was dependent on the lunar hour-angle, and whose period was therefore a lunar day. This singular result was subsequently confirmed by Mr. Broun, in his discussion of the Makerstoun Observations; and its laws have since been fully traced, for all the magnetic elements, by General Sabine, in the results obtained at the Colonial Magnetic Observatories.

The foregoing facts bear closely upon the debated question of the *causes* of the magnetic variations. It has been usual to ascribe the periodical changes of the Earth's magnetic force to the thermic action of the Sun, operating either *directly* upon the magnetism of the Earth, or affecting it *indirectly* by the induction of the thermo-electric currents. Here, however, we have a distinct case of magnetic action, unaccompanied by heat; and the question is naturally suggested, whether the solar diurnal change may not also be independent of temperature.

The most important fact, in its bearing upon this question, is the existence of an *annual inequality* in the diurnal variation, dependent on the Sun's declination, recently pointed out by General Sabine. If we deduct the ordinate of the curve, which represents the mean diurnal variation for the entire year, from those for the summer and winter half-yearly curves respectively, the differences are found to be equal and opposite; and the curves

which represent them are, consequently, *similar*, but *oppositely placed* with respect to the axis of abscissæ. From this General Sabine draws the inference, that the diurnal variation is a *direct effect of solar action*, and not a result of its thermic agency.

The most important step which has been recently taken in this country to advance the science of *Meteorology*, has been the formation of a department connected with the Board of Trade, for the collection and discussion of Meteorological Observations made *at sea*. The practical results of a similar undertaking in the United States are now well known. The charts and sailing directions, published by Lieutenant Maury, have enabled navigators to shorten their passages, in many cases by one-fourth of the time, and in some even to a greater extent. The commercial importance of such results could not fail to attract general attention; and accordingly, when the United States Government invited other maritime nations to cooperate in the undertaking, the invitation was cordially accepted. A conference was held at Brussels in 1853, at which meteorologists deputed by those Powers attended; and a Report was made, recommending the course to be pursued in a general system of marine meteorological observations. This Report was laid before the British Parliament soon after, and a sum of money was voted for the necessary expenditure. The British Association undertook to supply verified instruments, by means of its Observatory at Kew; and the Royal Society, in consultation with the most eminent meteorologists of Europe and America, addressed an able Report to the Board of Trade, in which the objects to be attended to, so as to render the system of observation most available for science, were clearly set forth. With this cooperation on the part of the two leading Scientific Societies, the establishment was soon organized. It was placed under the direction of a distinguished naval officer, Admiral FitzRoy; and in the beginning of 1855 it was in operation. Agents were established at the principal ports for the supply of instruments, books, and instructions; and there are now more than 200 British ships so furnished, whose officers have undertaken to make and record the required observations, and to transmit them from time to time to the Department. At the present time 700 months of logs have been received, from nearly 100 merchant ships, and are in process of tabulation.

Holland is taking similar steps; and the Meteorological Institute of that country, under the direction of Mr. Buys Bellot, has already published three volumes of nautical information, obtained from Dutch vessels in the Atlantic and Indian Ocean.

For the purposes of Meteorological Science this system cannot be considered as complete, until observations *on land* are included. Most of the greater atmospheric changes are due to the distribution of land and water, and to the different effects of the Sun's rays on each. Observation alone can furnish the data from which the effects of these agencies may be calculated; and we can therefore probably make no great advance in the knowledge

of the meteorology of the globe, without a *concurrent* investigation of its two leading departments. Land observations exist in great numbers. In Prussia, in Russia, in Austria, and in Belgium, such observations are organized under Government direction, or at least with Government support; in other parts of Europe, as in Britain, the labour is left to individuals or scientific societies. What is needed is to give *unity* to these isolated labours—to connect them with one another, and with the results obtained at sea; and the first step to this seems to be, to give them, in each country, that permanence and uniformity of system which can only be ensured in measures adopted by the State.

Here, however, we encounter an objection, upon which it is necessary to say a few words.

It has been objected to the Science of Meteorology, as it is usually studied, that it proceeds upon a *false method*; and that, consequently, it has led, and can lead, to *no results*. I feel myself in a manner compelled to notice this grave objection, in the first place, because it proceeds from men, whose opinions on this (or almost any other scientific question) are entitled to the highest deference; and secondly, because this Association must bear no inconsiderable measure of the reproach, if it be well founded.

First, then, as to *results*. I am free to admit that the number of those engaged in the *discussion* of meteorological observations is *disproportionately small*, and that the results obtained probably fall far short of what may be expected from the data already accumulated. But that the methods have led, and can lead, to no results, is, I think, sufficiently disproved by the labours of a single man—Professor Dove of Berlin. And if it be true that the course pursued in the science has yielded much fruit, in proportion to the labour bestowed on the discussion, it will hardly be deemed widely erroneous. Still, as it is possible that the methods pursued—though not *fruitless*—may be *inadequate*, it seems necessary to notice the objection somewhat more minutely.

It is asserted, then, that the capital vice of the Science of Meteorology, as at present pursued, is that it has *no definite aim*; that it ought to embrace an inquiry into the *physical constitution* of the objects with which the science is concerned, and an investigation of *causes* as well as *laws* of phenomena.

It may be admitted, at once, in reference to this objection, that the physical constitution of the bodies whose changes we are investigating is a proper object of study to the physicist; but it does not seem to follow that it should necessarily be conducted by the same individuals who are in search for the laws of the phenomena, or even that the former knowledge is essential to the progress of the latter. The noblest of all the physical sciences, Astronomy, is little more than a science of *laws*—laws, too, of the *simplest kind of change*; and the knowledge of these laws is wholly *independent of the physical constitution* of the masses whose movements it studies. A similar observation may be made regarding the science of *Terrestrial Magnetism*; and

the case is one which brings us still nearer to the question at issue, inasmuch as the laws which have been obtained—and they are numerous—have resulted from a method of inquiry altogether similar to that adopted in Meteorology.

Time will not permit me to inquire whether there is not a misconception of a metaphysical kind at the root of this objection. I may observe, however, before leaving the subject, that there are two modes of studying the sequences of natural phenomena,—one in their relation *to time*, and which is best accomplished by observations at stated periods, and the other in the relation of the *successive phases of the phenomenon to one another*. Of these, the latter, although not wholly neglected, has not been so much followed as it deserves; and I cannot but think that it would, if more systematically followed, enrich the science of Meteorology with a new harvest of results.

The most important of the recent additions to the theory of *Light* have been those made by M. Jamin. It has been long known that metals differed from transparent bodies, in their action on light, in this, that plane-polarized light reflected from their surfaces became *elliptically polarized*; and the phenomenon is explained, on the principles of the wave-theory, by the assumption that the vibration of the ether undergoes a *change of phase* at the instant of reflexion, the amount of which is dependent on its direction, and on the angle of incidence. This supposed distinction, however, was soon found not to be absolute. Mr. Airy showed that *diamond* reflected light in a manner similar to metals; and Mr. Dale and Professor Powell extended the property to all bodies having a high refractive power. But it was not until lately that M. Jamin proved that there is *no distinction*, in this respect, between transparent and metallic bodies; and that all bodies transform plane-polarized into elliptically-polarized light, and impress a change of phase at the moment of reflexion. Professor Haughton has followed up the researches of M. Jamin, and established the existence of *circularly-polarized* light by reflexion from transparent surfaces.

The theoretical investigations connected with this subject afford a remarkable illustration of one of those impediments to the progress of Natural Philosophy, which Bacon has put in the foremost place among his examples of the *Idola*,—I mean the tendency of the human mind to suppose a greater simplicity and uniformity in nature than exists there. The phenomena of polarization compel us to admit that the sensible luminous vibrations are *transversal*, or in the plane of the wave itself; and it was naturally supposed by Fresnel, and after him by MacCullagh and Neumann, either that no *normal* vibrations were propagated, or that, if they were, they were unconnected with the phenomena of light. We now learn that it is by them that the *phase* is modified in the act of reflexion; and that, consequently, no dynamical theory which neglects them, or sets them aside, can be complete.

Attention has been lately recalled to a fundamental position of the wave-theory of light, respecting which opposite assumptions have been made.

The vibrations of a polarized ray are all parallel to a fixed direction in the plane of the wave; but that direction may be either *parallel*, or *perpendicular* to the plane of polarization. In the original theory of Fresnel the latter was assumed to be the fact; and in this assumption Fresnel has been followed by Cauchy. In the modified theories of MacCullagh and Neumann, on the other hand, the vibrations are supposed to be parallel to the plane of polarization. This opposition of the two theories was compensated, as respects the results, by other differences in their hypothetical principles; and both of them have led to conclusions which observation has verified. There seemed, therefore, to be no means left to the theorist to decide between these conflicting hypotheses, until Professor Stokes, recently, in applying the dynamical theory of light to other classes of phenomena, found one in which the effects should differ on the two assumptions. When light is transmitted through a fine grating, it is turned aside, or *diffracted*, according to laws which the wave-theory has explained. Now Professor Stokes has shown that, when the incident light is *polarized*, the *plane of vibration* of the diffracted ray must differ from that of the incident, the two planes being connected by a very simple relation. It only remained, therefore, for observation to determine whether the *planes of polarization* of the incident and refracted rays were similarly related, or not. The experiment was undertaken by Professor Stokes himself, and he has inferred from it that the original hypothesis of Fresnel is the true one; but, as an opposite result has been obtained by M. Holtzmann, on repeating the experiment, the question must be regarded as still undetermined. The difference in the experimental results is ascribed by Professor Stokes to the difference in the nature of the gratings employed, the substance of the diffracting body being supposed to exert an effect upon the polarization of the light, which is diffracted by it under a great obliquity. I learn from Professor Stokes that he proposes to resume the experimental inquiry, and to test this supposition by employing gratings of various substances. If the conjecture should prove to be well founded, it will, unfortunately, greatly complicate the dynamical theory of light. In the meantime the hypothesis is one of importance in itself, and deserves to be verified or disproved by independent means. I would venture to suggest that it may be effectively tested by means of the beautiful *Interference-refractor* of M. Jamin, which the inventor has already applied to study the effects upon light produced by grazing a plate of any soluble substance enclosed in a fluid.

It is well known that the refractive index of bodies increases with their density; and the theory of emission has even expressed the law of their mutual dependence. That theory, it is true, is now completely overthrown by the decisive *experimentum crucis* of MM. Fizeau and Foucault. It was therefore probable, *à priori*, that this law—the only one peculiar to the theory—would be found wanting. Its truth has recently been put to an experimental test by M. Jamin. Water, it is known, has its maximum of density at about 40° of Fahrenheit; so that, if Newton's law were true, its

refractive index should also have a maximum value at the same temperature. This has been disproved by M. Jamin, by observing the interference of two rays, one of which has passed through air, and the other through water; and thus the last conclusion of the emission-theory has been set aside.

It would occupy too much of your time were I to touch, even lightly, upon the subject of the *chemical action of light*, and the many beautiful and important discoveries of the art to which it has given rise. I may, however, mention, as one of the latest of the marvels of *photography*, that M. Poitevin has succeeded in producing plates in relief, for the purposes of engraving, by the action of light alone. The process depends upon the change in the affinity for water, produced by the action of light upon a thin plate of gelatine, which is impregnated with bichromate of potash.

In the whole range of experimental science there is no fact more familiar, or longer known, than the development of *Heat* by friction. The most ignorant savage is acquainted with it,—it was probably known to the first generation of mankind. Yet, familiar as it is, the science of which it is the germ dates back but a very few years.

It was known from the time of Black, that heat disappeared in producing certain changes of state in bodies, and reappeared when the order of those changes was reversed; and that the amount of heat, thus converted, had a given relation to the effect produced. In one of these changes, namely evaporation, a definite mechanical force is developed, which is again absorbed when the vapour is restored by pressure to the liquid state. It was therefore not unnatural to conjecture, that in all cases in which heat is developed by mechanical action, or *vice versâ*, a definite relation would be found to subsist between the amount of the action, and that of the heat developed or absorbed.

This conjecture was put to the test of experiment by Mayer and Joule, in 1842, and was verified by the result. It was found that *heat* and *mechanical power* were *mutually convertible*; and that the relation between them was *definite*, 772 *foot-pounds* of motive power being equivalent to a *unit of heat*, that is, to the amount of heat requisite to raise a pound of water through one degree of Fahrenheit. The science of Thermo-dynamics, based upon this fact, and upon a few other obvious facts, or self-evident principles, has grown up in the hands of Clausius, Thomson, and Rankine, into large proportions, and is each day making fresh conquests from the region of the unknown.

Thus far the science of Heat is made to rest wholly upon the facts of experiment, and is independent of any hypothesis respecting the molecular constitution of bodies. The dynamical theory of heat, however, has materially aided in establishing true physical conceptions of the *nature of heat*. The old hypothesis of caloric, as a separate substance, was indeed rendered improbable by the experiments of Rumford and Davy, and by the reasonings

of Young; but it continued to hold its ground, and is interwoven into the *language* of science. It is now clearly shown to be self-contradictory; and to lead to the result, that the amount of heat in the universe may be indefinitely augmented. On the other hand, the identification of radiant heat with light, and the establishment of the wave-theory, left little doubt that heat consisted in a *vibratory movement* either of the molecules of bodies, or of the ether within them. Still, the relation of heat to bodies, and the phenomena of conduction, indicate a mechanism of a more complicated kind than that of light, and leave ample room for further speculation.

The only mechanical hypothesis (so far as I am aware) which is consistent with the present state of our knowledge of the phenomena of heat, is the theory of *molecular vortices* of Mr. Rankine. In this theory all bodies are supposed to consist of *atoms*, composed of *nuclei* surrounded with *elastic atmospheres*. The radiation of light and heat is ascribed to the transmission of oscillations of the nuclei; while *thermometric heat* is supposed to consist in circulating currents, or *vortices*, amongst the particles of their atmospheres, whereby they tend to recede from the nuclei, and to occupy a greater space. From this hypothesis Mr. Rankine has deduced all the laws of thermodynamics, by the application of known mechanical principles. He has also, from the same principles, deduced relations (which have been confirmed by experiment) between the pressure, density, and absolute temperature of elastic fluids, and between the pressure and temperature of ebullition of liquids.

The dynamical theory of heat enables us to frame some conjectures to account for the continuance of its supply, and even to speculate as to its source. The heat of the Sun is dissipated and lost by radiation, and must be progressively diminished unless its thermal energy be supplied. According to the measurements of M. Pouillet, the quantity of heat given out by the Sun in a year is equal to that which would be produced by the combustion of a stratum of coal seventeen miles in thickness; and if the Sun's capacity for heat be assumed equal to that of water, and the heat be supposed to be drawn uniformly from its entire mass, its temperature would thereby undergo a diminution of 2°·4 Fahr. annually.

On the other hand, there is a vast store of force in our System capable of conversion into heat. If, as is indicated by the small density of the Sun, and by other circumstances, that body has not yet reached the condition of incompressibility, we have, in the future approximation of its parts, a fund of heat probably quite large enough to supply the wants of the human family to the end of its sojourn here. It has been calculated that an amount of condensation, which would diminish the diameter of the Sun by only the ten-thousandth part, would suffice to restore the heat emitted in 2000 years.

Again, on our own Earth, *vis viva* is destroyed by friction in the ebb and flow of every tide, and must therefore reappear *as heat*. The amount of this must be considerable, and should not be overlooked in any estimation of the

physical changes of our globe. According to the computations of Bessel, 25,000 cubic miles of water flow, in every six hours, from one quarter of the earth to another. The store of mechanical force is thus diminished, and the temperature of our globe augmented, by every tide. We do not possess the data which would enable us to calculate the magnitude of these effects. All that we know with certainty is, that the *resultant effect* of all the thermal agencies to which the Earth is exposed, has undergone no perceptible change within the historic period. We owe this fine deduction to Arago. In order that the *date palm* should ripen its fruit, the mean temperature of the place must exceed 70° Fahr.; and, on the other hand, the *vine* cannot be cultivated successfully when the temperature is 72° or upwards. Hence the mean temperature of any place, at which these two plants flourished and bore fruit, must lie between these narrow limits, *i. e.* could not differ from 71° Fahr. by more than a single degree. Now, from the Bible we learn that both plants were *simultaneously* cultivated in the central valleys of Palestine, in the time of Moses, and its then temperature is thus definitively determined. It is the same at the present time; so that the mean temperature of this portion of the globe has not sensibly altered in the course of thirty-three centuries.

The future of physical science seems to lie in the path upon which three of our ablest British physicists have so boldly entered, and in which they have already made such large advances. I may therefore be permitted briefly to touch upon the successive steps in this lofty generalization, and to indicate the goal to which they tend.

It has been long known that many of the forces of nature are related. Thus heat is produced by *mechanical action*, when that is applied in bringing the atoms of bodies nearer by compression, or when it is expended in friction. Heat is developed by *electricity*, when the free passage of the latter is impeded; it is produced whenever *light is absorbed*; and it is generated by *chemical action*. A like interchangeability probably exists among all the other forces of nature, although in many the relations have not been so long perceived. Thus the development of electricity from chemical action dates from the observations of Galvani; and the production of magnetism by electricity from the discovery of Oersted.

The next great step was to perceive that the relation of the physical forces was *mutual*; and that of any two, compared together, either may stand to the other in the relation of *cause*.

With respect to heat and mechanical force, this has been long known. When a body is *compressed* by mechanical force, it gives out *heat*; and, on the other hand, when it is *heated*, it dilates, and evolves *power*. The knowledge of the action of electricity, in dissolving the bonds of chemical union, followed closely upon that of the inverse phenomenon, and the discovery of *electro-magnetism* by Oersted was soon followed by that of *magneto-electricity* by Faraday. With reason, therefore, it occurred to many minds that the relations of any two of the forces of nature were *mutual*;—that that which is the *cause*,

in one mode of interaction, may become the *effect*, when the order of the phenomena is changed;—and that therefore, in the words of Mr. Grove, one of the able expounders of these views, while they are "correlative" or reciprocally dependent, "neither, taken abstractedly, can be said to be the essential cause of the others."

But a further step remained to be taken. If these forces were not only related, but mutually related, was it not probable that the relation was also a *definite* one? Thus, when heat is developed by mechanical action, ought we not to expect a certain definite proportion to subsist between the interacting forces, so that if one were doubled or trebled in amount, the other should undergo a proportionate change? This anticipation, it has been already stated, has been realized by Mayer and Joule. The discovery of the mechanical equivalent of heat has been rapidly followed by that of other forces; and we now know not only that electricity, magnetism, and chemical action, in given quantities, will produce each a *definite amount of mechanical work*, but we know further—chiefly through the labours of Mr. Joule—what that relation is, or, in other words, *the mechanical equivalent of each force.*

The first step in this important career of discovery—though long unperceived in its relation to the rest—was, undoubtedly, Faraday's proof of the definite chemical effect of the voltaic current. The last will probably be to reduce all these phenomena to *modes of motion*, and to apply to them the known principles of dynamics, in such a way as not only to express the laws of each kind of movement, as it is in itself, but also the connexion and dependence of the different classes of the phenomena.

A bold attempt at such a generalization has been made by M. Helmholtz. The science of Thermo-dynamics starts from the principle, that *perpetual motion is impossible*, or, in other words, that we cannot, by any combination of natural bodies, produce force out of nothing. In mechanical force, this principle is reducible to the known law of the *conservation of living force*; and M. Helmholtz has accordingly endeavoured to show that this law is maintained in the interaction of all the natural forces; while, at the same time, the assumption of its truth leads to some new consequences in physics, not yet experimentally confirmed. Expressed in its most general form, this principle asserts that the *gain* of *vis viva* during the motion of a system, is equal to the *force consumed* in producing it; from which it follows, that the sum of the *vires vivæ*, and of the existing forces, is constant. This principle M. Helmholtz denominates the *conservation of force*. A very important consequence of its establishment must be, that all the actions of nature are due to attractive and repulsive forces, whose intensity is a function of the distance,—the conservation of *vis viva* holding only for such forces.

It is usually stated, in mechanical works, that there is a *loss* of *vis viva* in the *collision of inelastic bodies*, and in *friction*. This is true with respect to the *motion of masses*, which forms the subject of mechanical science as at present limited; but it is not true in a larger sense. In these, and such like

cases, the movement of masses is transformed into *molecular motion*, and thus reappears as heat, electricity, and chemical action; and the amount of the transformed action definitely corresponds to the mechanical force which was apparently lost.

In the cases just considered, mechanical action is converted into molecular. But molecular actions of different kinds are themselves in like manner interchangeable. Thus, when *light* is absorbed, *vis viva* is apparently lost; but—not to speak of *phosphorescence*, in which the light absorbed, or a portion of it, is again given out—in all such cases, heat and chemical action are developed, and in amount corresponding to the loss. Hence the apparent exceptions to the principle are in reality confirmations of it; and we learn that the quantity of force in nature is as unchangeable as the quantity of matter.

This, however, is not true of the quantity of *available force*. It follows from Carnot's law, that heat can be converted into mechanical work only when it passes from a warmer to a colder body. But the radiation and conduction by which this is effected, tend to bring about an *equilibrium of temperature*, and therefore to annihilate mechanical force: and the same destruction of energy is going forward in the other processes of nature. Thus, it follows from the law of Carnot, as Professor Thomson has shown, that the universe tends to a state of eternal rest; and that its store of available force must be at length exhausted, unless replenished by a new act of Creative Power.

Mr. Rankine has attempted, in another method, to combine the physical sciences into one system, by distinguishing the properties which the various classes of physical phenomena possess in common, and by taking for axioms propositions which comprehend their laws. The principles thus obtained are applicable *to all physical change*; and they possess all the certainty of the facts from which they are derived by induction. The subject-matter of the science so constituted is *energy*, or the capacity to effect changes; and its fundamental principles are—1st, that all kinds of energy and work are homogeneous, or, in other words, that any kind of energy may be made the means of performing any kind of work; and 2nd, that the total energy of a substance cannot be altered by the mutual action of its parts. From these principles the author has deduced some very general laws of the *transformation of energy*, which include the known relations of physical forces.

I have occupied your time so largely with the sciences of one section, that I cannot do more than advert to one or two topics connected with the others, which have struck my own mind, although, from my limited acquaintance with the subjects, I could not venture to say that they are absolutely the most deserving of notice.

Among the most remarkable of the recent discoveries in *inorganic chemistry* are those of MM. Wöhler and Deville, relative to *silicon* and *boron*. Each of these substances is now proved to exist in three very different states,

analogous to the three known states of *carbon*, to which they are thus closely allied, namely *charcoal*, *graphite*, and *diamond*. The last of these states is, of course, the most interesting. *Crystallized boron* possesses a hardness, brightness, and refractive power comparable to those of diamond; it burns in chlorine, without residue, and under circumstances resembling those of the combustion of diamond in oxygen; it is not acted on by any of the acids, and appears to be the least alterable of all the simple bodies. I have been informed that its powder is already used in the arts, instead of diamond dust; and it seems not improbable that, when obtained by the chemist in crystals of larger size, it may rival the diamond as a gem.

The science of *Geology* appears, of late years, to have entered upon a new phase of its development,—one characterized by a stricter reference of its speculative views to the principles of those sciences with which it is connected, and upon which it ought to be based. The able memoirs of Mr. Hopkins, on what may be called *dynamical geology*, afford a remarkable proof of this; and we have another instance of the application of sound physical principles to this science in the explanations which have been recently offered of the phenomena of *slaty cleavage*. A Report on this interesting subject was presented to the Association by Professor Phillips at its last Meeting, and will be found in the volume just published. These sounder views originate, I believe, with himself and with Mr. Sharpe; but they have been enlarged and confirmed by Mr. Sorby, Dr. Tyndall, and Professor Haughton.

We have an interesting proof of the readiness of geologists of the present day to submit their views to the test of exact observation, in the measurements undertaken by Mr. Horner for the purpose of approximating to the age of the sedimentary deposits. Of the geological changes still in operation, none is more remarkable than the formation of deltas at the mouths of great rivers, and of alluvial land by their overflow. Of changes of the latter kind, perhaps the most remarkable is the great alluvial deposit formed in the valley of the Nile by the annual inundations of that river; and here it fortunately happens that history comes to the aid of the geologist. These sedimentary deposits have accumulated round the bases of monuments of *known age*, and we are therefore at once furnished with a *chronometric scale* by which the rate of their formation may be measured. The first of the series of measurements undertaken by Mr. Horner was made, with the cooperation of the Egyptian Government, around the obelisk of Heliopolis, a monument built, according to Lepsius, 2300 years B.C. A more extensive series of researches has been since undertaken in the district of Memphis; but Mr. Horner has not yet, I believe, published the results.

The problems now to be solved in *Palæontology* are clearly defined in the enunciation of the problem recently proposed by the French Academy of Sciences as one of its prize questions, viz. " to study the laws of distribution

of organic beings in the different sedimentary rocks, according to the order of their superposition; to discuss the question of their appearance or disappearance, whether simultaneous or successive; and to determine the nature of the relations which subsist between the existing organic kingdom and its anterior states." The prize was obtained by Professor Bronn, of Heidelberg; and his memoir, of which I have only seen an outline, appears to be characterized by views at once sound and comprehensive. The leading result seems to be, that the genera and species of plants and animals, which geology proves to have existed successively on our globe, were *created in succession*, in adaptation to the existing state of their abode, and *not transmuted* or *modified*, as the theory of Lamarck supposes, by the physical influences which surrounded them.

I must now pass from the results of science to the administrative measures which have been adopted by this Association for its advancement, and more especially to those which will be brought under your consideration at the present Meeting.

One of the modes in which this Association most effectively promotes the advancement of Science is, you are aware, by the preparation and publication of Reports on the history, and actual state, of its several branches. With the help of these, original investigators may, with little labour, ascertain all that has been accomplished in each department, before they proceed to increase the store; and so not only prepare their own minds for their task, but also avoid the waste of time and toil which has been too often incurred in the re-discovery of the same truths.

To further the same objects, it was proposed by Professor Henry, of Washington, at the Glasgow Meeting of the Association, that a Catalogue of papers occurring in the Transactions of Scientific Societies, and in the Scientific Journals, should be prepared by the Association, the Smithsonian Institution undertaking to execute that part of the work which related to American Science. A Committee, consisting of Mr. Cayley, Mr. Grant, and Professor Stokes, was appointed to consider this proposal, and their Report was submitted to the Cheltenham Meeting. The subject has since been under the consideration of the Council of the Royal Society; and a preliminary Report has been drawn up by a sub-Committee of that body, which will probably be brought before your Committee at this meeting.

A still more important question has been, for some years, under the consideration of this Association and the Royal Society—the question, namely, whether any measures could be adopted by the Government, or Parliament, that would improve the position of Science or its cultivators in this country.

The Parliamentary Committee of the Association have taken much pains in the attempt to arrive at a solution of this large and complex question. They consulted, in the first instance, several of the most eminent scientific men of this country; and in their first Report, presented to the Meeting of

the Association at Glasgow, they have analysed the replies obtained, and have recommended certain general measures founded thereon. The most important of these recommendations are the provision, at the cost of the nation, of a central building in London, in which the principal Scientific Societies of the metropolis may be located together; and the formation of a Scientific Board, to have the control and expenditure of the public funds allotted to the advancement of science. This Report was brought under the consideration of your Committee of Recommendations at the last two Meetings of the Association; and the opinions of the members of the General Committee have been since invited in reference to its suggestions. The Council of the Royal Society have likewise deliberated on the same question, and have passed certain resolutions on the subject, which accord in substance with the conclusions of the Parliamentary Committee. A copy of these resolutions was forwarded by Lord Wrottesley, as President of the Society, to Lord Palmerston; and motions have been made in both Houses of Parliament for the production of the correspondence.

The first of the objects above referred to—namely, the juxtaposition of the Scientific Societies of London in one locality—has been since accomplished by the grant of Burlington House for the use of the Royal, Linnæan, and Chemical Societies; and the result affords a fresh instance of the readiness of Her Majesty's Government to listen to, and comply with, the suggestions of men of science, when deliberately and carefully made. I cannot but think that this important step is fraught with consequences affecting the promotion of science, and extending far beyond the external and obvious advantages, which it ensures to the Scientific Societies more immediately benefited.

Another mode in which this Association has materially aided in the advancement of science is through the instrumentality of its Observatory at Kew. The objects which are at present attained by that important establishment are, the trial and improvement of instrumental methods, and especially of those connected with the *photographic registration* of natural phenomena; the *verification* of meteorological instruments, and the construction of *standard* barometers and thermometers; the supervision of apparatus to be employed by scientific travellers, and the instruction of the observers in their use; and lastly, the conduct of *special experimental researches*, undertaken by members of the Association at its request. In all these various ways, the labours of the Kew Observatory have tended, in no small degree, to the advancement of the sciences of Observation and Experiment in this country; and the result is due, not only to the sagacity of the Committee under whose management it is placed, but also, and eminently, to the zeal and talents of Mr. Welsh, and the gentleman who has the immediate charge of the establishment.

There is but one other topic connected with the administration of the

Association to which I feel it necessary to invite your attention before I conclude,—I mean the change which has been made in the constitution of one of the Sections, and which will come into operation at the present Meeting.

By a resolution of your Committee, adopted at the last Meeting, the scope of the "Statistical Section" has been enlarged, and it now embraces *Economic Science* in all its relations. I regard it as a fortunate circumstance for the Association, that this important change will come into operation under the Presidency of the distinguished prelate, whose talents have been so long devoted to the advancement of this science, and to whose munificence we owe the formation of a shool of Political Economy in the University of Dublin, which has already attained a high measure of celebrity. The Section will have the aid, on this occasion, of more than one of those gentlemen who have filled the Chair of the Whately Professorship, as well as of other members of the Statistical Society of Dublin; and its proceedings will receive the countenance and support of many foreigners who have devoted themselves to the cultivation of Economic Science.

Gentlemen, suffer me now to thank you for the indulgent attention with which you have favoured me. I am conscious that the sketch of the recent progress of the Physical Sciences, which I have endeavoured to present, is but a meagre and imperfect summary of what has been accomplished; but it is enough, at all events, to prove that Science is not on the decline, and that its cultivators have not been negligent in their high calling. I now beg, in the name of the Local Members of this body, to welcome you warmly to this city; and I pray that your labours here may redound to the glory of God, and to the welfare and happiness of your fellow-men.

REPORTS

ON

THE STATE OF SCIENCE.

REPORTS

ON

THE STATE OF SCIENCE.

Report on the Recent Progress of Theoretical Dynamics. *By* A. Cayley.

The object of the 'Mécanique Analytique' of Lagrange is described by the author in the 'Avertissement' to the first edition as follows:—"On a dejà plusieurs traités de mécanique, mais le plan de celui-ci est entièrement neuf. Je me suis proposé de réduire la théorie de cette science et l'art de résoudre tous les problêmes qui s'y rapportent à des formules générales dont le simple développement donne toutes les équations nécessaires pour la solution de chaque problême." And the intention is carried out; the principle of virtual velocities furnishes the general formulæ for the solution of statical problems, and D'Alembert's principle then leads to the general formulæ for the solution of dynamical problems. The general theory of statics would seem to admit of less ulterior development; but as regards dynamics, the formulæ of the first edition of the 'Mécanique Analytique' have been the foundation of a series of profound and interesting researches constituting the science of analytical dynamics. The present report is designed to give, so far as I am able, a survey of these researches; there will be found at the end a list, in chronological order, of the works and memoirs referred to, and I shall in the course of the report preserve as far as possible the like chronological order. It is proper to remark that I confine myself to the general theories of dynamics. There are various *special problems* of great generality, and susceptible of the most varied and extensive developments, such for instance as the problem of the motion of a single particle (which includes as particular cases the problem of central forces, that of two fixed centres, and that of the motion of a conical pendulum, either with or without regard to the motion of the earth round its axis), the problem of three bodies, and the problem of the rotation of a solid body about a fixed point. But a detailed account of the researches of geometers in relation to these special problems would properly form the subject of a separate report, and it is not my intention to enter upon them otherwise than incidentally, so far as it may appear desirable to do so. One problem, however, included in the first of the abovementioned special problems, I shall have frequent occasion to allude to: I mean the problem of the variation of the elements of a planet's orbit, which has a close historical connexion with the general theories which form the subject of this report. The so-called ideal coordinates of Hansen, and the principles of his method of integration in the planetary and lunar theories, have a bearing on the general subject, and might have been considered in the present report; but on the whole I have considered it better not to do so.

1. Lagrange, 'Mécanique Analytique,' 1788.—The equations of motion are obtained, as before mentioned, by means of the principle of virtual velo-

cities and D'Alembert's principle. In their original forms they involve the coordinates x, y, z of the different particles m or dm of the system, quantities which in general are not independent. But Lagrange introduces, in place of the coordinates x, y, z of the different particles, any variables or (using the term in a general sense) coordinates $\xi, \psi, \phi, \ldots$ whatever, determining the position of the system at the time t: these may be taken to be independent, and then if $\xi', \psi', \phi', \ldots$ denote as usual the differential coefficients of $\xi, \psi, \phi, \ldots$ with respect to the time, the equations of motion assume the form

$$\frac{d}{dt}\frac{d\mathrm{T}}{d\xi'}-\frac{d\mathrm{T}}{d\xi}+\Xi=0\,;$$
$$\vdots$$

or when $\Xi, \Psi, \Phi, \ldots$ are the partial differential coefficients with respect to $\xi, \psi, \phi, \ldots$ of one and the same function V, then the form

$$\frac{d}{dt}\frac{d\mathrm{T}}{d\xi}-\frac{d\mathrm{T}}{d\xi'}+\frac{d\mathrm{V}}{d\xi}=0.$$
$$\vdots$$

In these equations, T, or the *vis viva* function, is the *vis viva* of the system or sum of all the elements, each into the half square of its velocity, expressed by means of the coordinates $\xi, \psi, \varphi, \ldots$; and (when such function exists) V, or the force function*, is a function depending on the impressed forces and expressed in like manner by means of the coordinates $\xi, \psi, \phi, \ldots$; the two functions T and V are given functions, by means of which the equations of motion for the particular problem in hand are completely expressed. In any dynamical problem whatever, the *vis viva* function T is a given function of the coordinates $\xi, \psi, \phi, \ldots$, of their differential coefficients $\xi', \psi', \phi', \ldots$ and of the time t; and it is of the second order in regard to the differential coefficients $\xi', \psi', \phi', \ldots$; and (when such function exists) the force function V is a given function of the coordinates $\xi, \psi, \phi, \ldots$ and of the time t. This is the most general form of the functions T, V, as they occur in dynamical problems, but in an extensive class of such problems the forms are less general, viz. T and V are each of them independent of the time, and T is a homogeneous function of the second order in regard to the differential coefficients $\xi', \psi', \phi', \ldots$; the equations of motion have in this case an integral $\mathrm{T}+\mathrm{V}=h$, which is the equation of *vis viva*, and the problems are distinguished as those in which the principle of *vis viva* holds good. It is to be noticed also that in this case since t does not enter into the differential equations, the integral equations will contain t in the form $t+c$, that is, in connexion with an arbitrary constant c attached to it by addition.

2. The above-mentioned form is *par excellence* the Lagrangian form of the equations of motion, and the one which has given rise to almost all the ulterior developments of the theory; but it is proper just to refer to the form in which the equations are in the first instance obtained, and which may be called the unreduced form, viz. the equations for the motion of a particle whose rectangular coordinates are x, y, z, are

$$m\frac{d^2x}{dt^2}=\mathrm{X}+\lambda\frac{d\mathrm{L}}{\delta x}+\mu\frac{d\mathrm{M}}{\delta x}+\ldots$$
$$\vdots$$

where $\mathrm{L}=0$, $\mathrm{M}=0, \ldots$ are the equations of condition connecting the coordinates of the different points of the system, and $\lambda, \mu, \ldots$ are indeterminate multipliers.

* The sign attributed to V is that of the 'Mécanique Analytique,' but it would be better to write $\mathrm{V}=-\mathrm{U}$, and to call U (instead of V) the force function.

3. The idea of a force function seems to have originated in the problems of physical astronomy. Lagrange, in a memoir 'On the Secular Equation of the Moon,' crowned by the French Academy of Sciences in the year 1774, expressed the attractive forces, decomposed in the directions of the axes of coordinates, by the partial differential coefficients of one and the same function with respect to these coordinates. And it was in these problems natural to distinguish the forces into principal and disturbing forces, and thence to separate the force function into two parts, a principal force function and a disturbing function. The problems of physical astronomy led also to the idea of the variation of the arbitrary constants of a mechanical problem. For as a fact of observation the planets move in ellipses the elements o which are slowly varying; the motion in a fixed ellipse was accounted for by the principal force, the attraction of the sun; the effect of the disturbing force is to produce a continual variation of the elements of such elliptic orbit. Euler, in a memoir published in 1749 in the 'Memoirs of the Academy of Berlin' for that year, obtained differential equations of the first order for two of the elements, viz. the inclination and the longitude of the node, by making the arbitrary constants which express these elements in the fixed orbit to vary: this seems to be the first attempt at the method of the variation of the arbitrary constants. Euler afterwards treated the subject in a more complete manner, and the method is also made use of by Lagrange in his 'Memoir on the Perturbations of the Planets' in the Berlin Memoirs for 1781, 1782, 1783, and by Laplace in the 'Mécanique Céleste,' t. i. 1799. The method in its original form seeks for the expressions of the variations of the elements in terms of the differential coefficients of the disturbing function *with respect to the coordinates*. As regards one element, the longitude of the epoch, such expression (at least in a finite form) was first obtained by Poisson in his memoir of 1808, to be spoken of presently; but I am not able to refer to any place where such expressions in their best form are even now to be found; the question seems to have been unduly passed over in consequence of the new form immediately afterwards assumed by the method. It was very early observed that the variation of one of the elements, viz. the mean distance, was expressible in a remarkable form by means of the differential coefficients of the disturbing function *taken with respect to the time t, in so far as it entered into the function through the coordinates of the disturbed planet.* I am not able to say at what time, or whether by Euler, Lagrange, or Laplace, it was observed that such differential coefficient with respect to the time was equivalent to the differential coefficient of the disturbing function with respect to one of the elements. But however this may be, the notion of the representation of the variations of the elements by means of the differential coefficients of the disturbing function *with respect to the elements* had presented itself *à posteriori*, and was made use of in an irregular manner prior to the year 1800, and therefore some eight years at any rate before the establishment by Lagrange of the general theory to which these forms belong.

4. Poisson's memoir of the 20th of June, 1808, 'On the Secular Inequalities of the Mean Motion of the Planets,' was presented by him to the Academy at the age of twenty-seven years. It contains, as already remarked, an expression in finite terms for the variation of the longitude of the epoch. But the memoir is to be considered rather as an application of known methods to an important problem of physical astronomy, than as a completion or extension of the theory of the variation of the planetary elements. The formulæ made use of are those involving the differential coefficients of the disturbing function with respect to the *coordinates*; and

there is nothing which can be considered an anticipation of Lagrange's idea of the investigation, *à priori*, of expressions involving the differential coefficients with respect to the elements. But as well for its own sake as historically, the memoir is a very important one. Lagrange, in his memoir of the 17th of August, 1808, speaks of it as having recalled his attention to a subject with which he had previously occupied himself, but which he had quite lost sight of; and Arago records that, on the death of Lagrange, a copy in his own handwriting of Poisson's memoir was found among his papers; and the memoir is referred to in, and was probably the occasion of, Laplace's memoir also of the 17th of August, 1808.

5. With respect to Laplace's memoir of the 17th of August, 1808, it will be sufficient to quote a sentence from the introduction to Lagrange's memoir:—" Ayant montré à M. Laplace mes formules et mon analyse, il me montra de son côté en même temps des formules analogues qui donnent les variations des élémens elliptiques par les différences partielles d'une même fonction, relatives à ces élémens. J'ignore comment il y est parvenu ; mais je présume qu'il les a trouvées par une combinaison adroite des formules qu'il avait donné dans la 'Mécanique Céleste.'" This is, in fact, the character of Laplace's analysis for the demonstration of the formulæ.

6. In Lagrange's memoir of the 17th of August, 1808, 'On the Theory of the Variations of the Elements of the Planets, and in particular on the Variations of the Major Axes of their Orbits,' the question treated of appears from the title. The author obtains formulæ for the variations of the elements of the orbit of a planet in terms of the differential coefficients of the disturbing function with respect to the elements; but the method is a general one, quite independent of the particular form of the integrals, and the memoir may be considered as the foundation of the general theory. The equations of motion are considered under the form,—

$$\frac{d^2x}{dt^2}-\frac{1+m}{r^3}x=\frac{d\Omega}{dx},$$

$$\frac{d^2y}{dt^2}-\frac{1+m}{r^3}y=\frac{d\Omega}{dy},$$

$$\frac{d^2z}{dt^2}-\frac{1+m}{r^3}z=\frac{d\Omega}{dz},$$

and it is assumed that the terms in Ω being neglected, the problem is completely solved, viz., that the three coordinates, x, y, z, and their differential coefficients, x', y', z', are each of them given as functions of t, and of the constants of integration a, b, c, f, g, h; the disturbing function Ω is consequently also given as a function of t, and of the arbitrary constants. The velocities are assumed to be the same as in the undisturbed orbit. This gives the conditions

$$\delta x=0,\ \delta y=0,\ \delta z=0;$$

and then the equations of motion give

$$\delta\frac{dx}{dt}=\frac{d\Omega}{dx},\ \delta\frac{dy}{dt}=\frac{d\Omega}{dy},\ \delta\frac{dz}{dt}=\frac{d\Omega}{dz}$$

equations in which δx, &c. denote the variations of x, &c., arising from the variations of the arbitrary constants, viz., $\delta x=\frac{dx}{da}\delta a+\frac{dx}{db}\delta b+$, &c. The differential coefficients $\frac{d\Omega}{\delta x}$, &c., can of course be expressed by means of

$\frac{d\Omega}{da}$, &c.; and, by a simple combination of the several equations, Lagrange deduces expressions for $\frac{d\Omega}{da}$, &c., in terms of $\frac{da}{dt}$, &c.; viz.—

$$\frac{d\Omega}{da}=(a,b)\frac{db}{dt}+(a,c)\frac{dc}{dt}+(a,f)\frac{df}{dt}+(a,g)\frac{dg}{dt}+(a,h)\frac{dh}{dt},$$
$$\vdots$$

where* $$(a,b)=\frac{\partial(x,x')}{\partial(a,b)}+\frac{\partial(y,y')}{\partial(a,b)}+\frac{\partial(z,z')}{\partial(a,b)},$$

in which, for shortness,

$$\frac{\partial(x,x')}{\partial(a,b)} \text{ stands for } \frac{dx}{da}\frac{dx'}{db}-\frac{dx'}{da}\frac{dx}{ab}.$$

The form of the expressions shows at once that $(a,b)=-(b,a)$, so that the number of the symbols (a,b) is in fact fifteen.

Lagrange proceeds to show, that the differential coefficient with respect to t of the expression represented by the symbol (a,b) vanishes identically; and it follows, that the coefficients (a,b) are *functions of the elements only, without the time t.*

The general formulæ are applied to the problem in hand; and, in consequence of the vanishing of several of the coefficients (a,b), it is easy in the particular problem to pass from the expressions for $\frac{d\Omega}{da}$, &c. in terms of $\frac{da}{dt}$, &c. to those for $\frac{da}{dt}$, &c. in terms of $\frac{d\Omega}{da}$, &c. The author thus obtains an elegant system of formulæ for the variations of the elements of a planet's orbit, in terms of the differential coefficients of the disturbing function with respect to the elements; but it is not for the present purpose necessary to consider the form of the system, or the astronomical consequences deduced by means of it.

7. Lagrange's memoir of the 13th of March, 1809, 'On the General Theory of the Variation of the Arbitrary Constants in all the Problems of Mechanics.'—The method of the preceding memoir is here applied to the general problem; the equations of motion are considered under the form

$$\frac{d}{dt}\frac{dT}{dr'}-\frac{dT}{dr}+\frac{dV}{dr}=\frac{d\Omega}{dr},$$
$$\vdots$$

where T and V are of the degree of generality considered in the 'Mécanique Analytique,' viz., T is a function of $r, s\ldots r', s',\ldots$ homogeneous of the second order as regards the differential coefficients $r', s',\ldots$, and V is a function of $r, s,\ldots$ only; or, rather, the equations are considered in a form obtained from the above, by writing $T-V=R$, viz., in the form

$$\frac{d}{dt}\frac{dR}{dr'}-\frac{dR}{dr}=\frac{d\Omega}{dr},$$
$$\vdots$$

and, as in the preceding memoir, expressions are investigated for the differential coefficients $\frac{d\Omega}{dt}$, &c, in terms of $\frac{db}{dt}$, &c.: these are, as before, of the

* These are substantially the formulæ of Lagrange; but I have introduced here and elsewhere the very convenient abbreviation, due, I think, to Prof. Donkin, of the symbols $\frac{\partial(x,x')}{\partial(a,b)}$.

form
$$\frac{d\Omega}{da}=(a, b)\frac{db}{dt}+, \&c.$$
where (a, b), &c., are in the body of the memoir obtained under a somewhat complicated form, and this complicates also the demonstration which is there given of the theorem, that (a, b), &c., *are functions of the elements only, without the time t*; but in the addition (published as part of the memoir, and without a separate date) and in the supplement the investigation is simplified, and the true form of the functions (a, b) obtained, viz., writing $\frac{d\mathrm{T}}{dr}=\rho, \ldots$ then
$$(a,b)=\frac{\partial(r,\rho)}{\partial(a,b)}+\frac{\partial(s,\sigma)}{\partial(a,b)}+\ldots$$
if, for shortness,
$$\frac{\partial(r,\rho)}{\partial(a,b)}=\frac{dr}{da}\frac{d\rho}{db}-\frac{d\rho}{da}\frac{dr}{db}, \&c.$$
The representation of $\frac{d\mathrm{T}}{dr'}, \frac{d\mathrm{T}}{ds'}$, &c. by single letters *is* made by Lagrange in the addition, No. 26 (Lagrange writes $\frac{d\mathrm{T}}{dr'}=\mathrm{T}'$, $\frac{d\mathrm{T}}{ds'}=\mathrm{T}''$, &c.), but quite incidentally in that number only, for the sake of the formula just stated: I have noticed this, as the step is an important one.

8. It is proper to remark that, in order to prove that the expressions (a, b) &c., are independent of the time, Lagrange, instead of considering the differential coefficients of each of these functions separately, establishes a general equation (see Nos. 25, 34, 35 of the Addition, and also the Supplement)
$$\frac{d}{dt}\left(\Delta r\delta\frac{d\mathrm{R}}{dr'}-\delta r'\Delta\frac{d\mathrm{R}}{dr'}+\ldots\right)=0,$$
where, if $\Delta a, \Delta b, \ldots$ denote any arbitrary increments whatever of the constants of integration $a, b, \ldots$ then Δr, &c., are the corresponding increments of the coordinates r, &c.; this is, in fact, a grouping together of several distinct equations by means of arbitrary multipliers, and it is extremely elegant as a method of demonstration, and has been employed as well by Lagrange, here and elsewhere, as by others who have written on the subject; but I think the meaning of the formulæ is best seen when the component equations of the group are separately exhibited, and in the citation of formulæ I have therefore usually followed this course. Lagrange gives also an equation which is in fact a condensed form of the preceding expression for $\frac{d\Omega}{da}$, but which it is proper to mention, viz.:—
$$\frac{d\Omega}{da}dt=\frac{dr}{da}\delta\frac{d\mathrm{R}}{dr'}+\ldots-\delta r\frac{d}{da}\frac{d\mathrm{R}}{dr'}-\ldots$$
In fact, in the formula $\delta\,\frac{d\mathrm{R}}{dr}$ stands for $\left(\frac{d}{da}\frac{d\mathrm{R}}{dr'}\frac{da}{dt}+\frac{d}{db}\frac{d\mathrm{R}}{dr}\frac{db}{dt}+\ldots\right)dt$, and δr for $\left(\frac{dr}{da}\frac{da}{dt}+\frac{dr}{dt}\frac{db}{dt}+\right)dt$; and, on substituting these values, the identity of the two expressions is seen without difficulty.

9. Lagrange remarks, that in the case where the condition of *vis viva* holds good, then if a be the constant of *vis viva* $(\mathrm{T}+v=a)$, and c the constant attached by addition to the time, then $\frac{da}{dt}=\frac{d\Omega}{dc}$, which, he observes,

is an equation remarkable as well from its simplicity and generality as because it can be obtained *à priori*, independently of the variations of the other arbitrary constants: this is obviously the generalisation of the expression for the variation of the mean distance of a planet.

10. The consideration of Lagrange's function (a, b) originated, as appears from what has preceded, in the theory of the variation of the elements; but it is to be noticed, that the function (a, b) is altogether independent of the disturbing function, and the fundamental theorem that (a, b) is a function of the elements only, without the time, is a property of the undisturbed equations of motion. The like remark applies to Poisson's function (a, b), in the memoir next spoken of.

11. Poisson's memoir of the 16th of October, 1809. The formulæ of this memoir are, so to speak, the reciprocals of those of Lagrange. The relations between the differential coefficients $\frac{d\Omega}{da}$, &c., of the disturbing function and the variations $\frac{da}{dt}$, &c., of the elements, depend with Lagrange, upon expressions for the coordinates and their differential coefficients in terms of the time and the elements; with Poisson, on expressions for the elements in terms of the time, and of the coordinates and their differential coefficients. The distinction is far more important than would at first sight appear, and the theory of Poisson gives rise to developments which seem to have nothing corresponding to them in the theory of Lagrange. The reason is as follows: when the system of differential equations is completely integrated, it is of course the same thing whether we have the integral equations in the form made use of by Lagrange, or in that by Poisson, the two systems are precisely equivalent the one to the other; but when the equations are not completely integrated, suppose, for instance, we have an expression for one of the coordinates in terms of the time and the elements, it is impossible to judge whether this is or is not one of the integral equations; the differential equations are not satisfied by means of this equation alone, but only by this equation with the assistance of the other integral equations. On the other hand, when we have an expression for one of the constants of integration in terms of the time, and of the coordinates and their differential coefficients, it is possible, by mere substitution in the differential equations, and without the knowledge of any other integral equations, to see that the differential equations are satisfied, and that the assumed expression is, in fact, one of the system of integral equations. An expression of the form just referred to, viz., $c=\phi\,(t, x, y, \ldots x', y' \ldots)$, where the right-hand side does not contain any of the arbitrary constants, may, with great propriety, be termed an "integral," as distinguished from an integral equation, in which the constants and variables may enter in any conceivable manner; it is convenient also to speak of such equation simply as the integral c.

12. Returning now to the consideration of Poisson's memoir, the equations of motion are considered under the same form as by Lagrange, viz., putting $\mathrm{T}-\mathrm{V}=\mathrm{R}$ under the form

$$\frac{d}{dt}\frac{d\mathrm{R}}{d\phi'}-\frac{d\mathrm{R}}{d\phi}=\frac{d\Omega}{d\phi};$$

but Poisson writes

$$\frac{d\mathrm{R}}{d\phi}=s, \ldots$$

thus, in effect, introducing a new set of variables, $s, \ldots$ equal in number to

the coordinates $\phi, \ldots$, but he does not complete the transformation of the differential equations by the introduction therein of the new variables $s, \ldots$ in the place of the differential coefficients $\phi', \ldots$; this very important transformation was only effected a considerable time afterwards by Sir W. R. Hamilton. Poisson then assumes that the undisturbed equations are integrated in the form above adverted to, viz., that the several elements $a, b \ldots$ are given as functions of the time t, and of the coordinates ϕ, &c., and their differential coefficients ϕ', &c., or what is the form ultimately assumed, as functions of the time t, of the coordinates $\phi, \ldots$, and of the new variables s, &c.; and he then forms the functions

$$(a, b)=\frac{\partial(a, b)}{\partial(s, \phi)}+\ldots$$

where

$$\frac{\partial(a, b)}{\partial(s, \phi)}=\frac{da}{ds}\frac{db}{d\phi}-\frac{db}{ds}\frac{da}{d\phi}$$

(the notation is the abbreviated one before referred to), and he proves by differentiation that the differential coefficient of (a, b) with respect to the time vanishes: that is, that (a, b) which, by its definition is given as a function of t and of the coordinates $\phi, \ldots$, and of the new variables $s, \ldots$, is really a constant. Upon which Poisson remarks—"On conçoit que la constante ... sera en général une fonction de a et b et des constantes arbitraires contenues dans les autres intégrales des équations du mouvement; quelquefois il pourra arriver que sa valeur ne renferme ni la constante a ni la constante b; dans d'autres cas elle ne contiendra aucune constante arbitraire, et se réduira à une constante déterminée; mais afin," &c.

13. The importance of the remark seems to have been overlooked until the attention of geometers was called to it by Jacobi; it has since been developed by Bertrand and Bour.

It is clear from the definition that $(a, b)=-(b, a)$. It may be as well to remark that the denominator of the functional symbol is (s, ϕ) and not (ϕ, s), which would reverse the sign.

14. The equations for the variations of the elements are without difficulty shown to be

$$\frac{da}{dt}=(a, b)\frac{d\Omega}{db}+\ldots$$
$$\vdots$$

which have the advantage over those of Lagrange of giving directly $\frac{da}{dt}$, &c. in terms of $\frac{d\Omega}{da}$, &c., instead of these expressions having to be determined from the value of $\frac{d\Omega}{da}$, &c., in terms of $\frac{da}{dt}$, &c.

15. Poisson applies his formulæ to the case of a body acted upon by a central force varying as any function of the distance, and also to the case of a solid body revolving round a fixed point. There is, as Poisson remarks, a complete similarity between the formulæ for these apparently very different problems, but this arises from the analogy which exists between the arbitrary constants chosen in the memoir for the two problems. The formulæ obtained form a very simple and elegant system, and one which, although not actually of the canonical form (the meaning of the term will be presently explained), might by a slight change be reduced to that form.

16. I may notice here a problem suggested by Poisson in a report to the Institute in the year 1830, on a manuscript work by Ostrogradsky on

Celestial Mechanics, viz., in the case of a body acted upon by a central force, the effect of a disturbing function, *which is a function only of the distance from the centre,* is merely to alter the amount of the central force; and the expressions for the variations of the elements should therefore, in the case in question, admit of exact integration; the report is to be found in *Crelle*, t. vii. pp. 97–101.

17. The two memoirs of Lagrange and Poisson, which have been considered, establish the general theory of the variation of the arbitrary constants, and there is not, I think, very much added to them by Lagrange's memoir of 1810, the second edition of the 'Mécanique Analytique,' 1811, or Poisson's memoir of 1816. The memoir by Maurice, in 1844, belongs to this part of the subject, and as its title imports, it is in fact a development of the theories of Lagrange and Poisson.

18. There is, however, one important point which requires to be adverted to. Lagrange, in the memoir of 1810, and the second edition of the 'Mécanique Analytique,' remarks, that for a particular system of arbitrary constants, viz., if $a, \ldots$ denote the initial values of the coordinates $\xi, \ldots$ and $\lambda, \ldots$ denote the initial values of $\frac{dT}{d\xi'}, \ldots$ then the equations for the variations of the elements take the very simple form

$$\frac{da}{dt} = -\frac{d\Omega}{d\lambda}, \ldots, \quad \frac{d\lambda}{dt} = \frac{d\Omega}{da}, \ldots$$

This is, in fact, the original idea and simplest example of a system of canonical elements; viz. of a system composed of pairs of elements, a, λ, the variations of which are given in the form just mentioned.

19. The 'Avertissement' to the second edition of the 'Mécanique Analytique' contains the remark, that it is not necessary that the disturbing function Ω should actually exist; $\frac{d\Omega}{dx}, \frac{d\Omega}{dy}, \frac{d\Omega}{dz}$ may be considered as mere conventional symbols standing for forces X, Y, Z, not the differential coefficients of one and the same function, and then $\frac{d\Omega}{da}$ will be a conventional symbol standing for $\frac{d\Omega}{dx}\frac{dx}{da} + \frac{d\Omega}{dy}\frac{dy}{da} + \frac{d\Omega}{dz}\frac{dz}{da}$, and similarly for $\frac{d\Omega}{db}$, &c.; and this being so, all the formulæ will subsist as in the case of an actually existing disturbing function.

20. Cauchy, in a note in the 'Bulletin de la Société Philomatique' for 1819 (reproduced in the 'Mémoire sur l'Intégration des Equations aux Derivées Partielles du Premier Ordre,' 'Exer. d'Anal. et de Physique Math.,' t. ii. pp. 238–272 (1841)), showed that the integration of a partial differential equation of the first order could be reduced to that of a single system of ordinary differential equations. A particular case of this general theorem was afterwards obtained by Jacobi in the course of his investigations (founded on those of Sir W. R. Hamilton) on the equations of dynamics, and he was thence led to a slightly different form of the general theorem previously established by Cauchy, viz., Cauchy's method gives the *general*, Jacobi's the *complete* integral, of the partial differential equation. The investigations of the geometers who have written on the theory of dynamics are based upon those of Sir W. R. Hamilton and Jacobi, and it is therefore unnecessary, in the present report, to advert more particularly to Cauchy's very important discovery.

21. I come now to Sir W. R. Hamilton's memoirs of 1834 and 1835, which are the commencement of a second period in the history of the sub-

ject. The title of the first memoir shows the object which the author proposed to himself, viz., the discovery of a function by means of which the integral equations can be all of them actually represented. The method given for the determination of this function, or rather of each of the several functions which answer the purpose, presupposes the knowledge of the integral equations; it is therefore not a *method of integration*, but a theory of the representation of the integral equations assumed to be known. I venture to dissent from what appears to have been Jacobi's opinion, that the author missed the true application of his discovery; it seems to me, that Jacobi's investigations were rather a theory collateral to, and historically arising out of the Hamiltonian theory, than the course of development which was of necessity to be given to such theory. But the new form obtained in Sir W. R. Hamilton's memoirs for the equations of motion, is a result of not less importance than that which was the professed object of the memoirs.

22. Hamilton's principal function V.—The formulæ are given for the case of any number of free particles, but, for simplicity, I take the case of a single particle. The equations of motion are taken to be

$$m\frac{d^2x}{dt^2}=\frac{dU}{dx},$$

$$m\frac{d^2y}{dt^2}=\frac{dU}{dy},$$

$$m\frac{d^2y}{dt^2}=\frac{dU}{dz};$$

so that the *vis viva* function is

$$T=\tfrac{1}{2}m(x'^2+y'^2+z'^2),$$

and the force function, taken with Lagrange's sign, would be $-U$. It is assumed that the condition of *vis viva* holds, that is, that U is a function of x, y, z only. The initial values of the coordinates are denoted by a, b, c, and those of the velocities by a', b', c'. The equation of *vis viva* is $T=U+H$, and this gives rise to an equation $T_0=U_0+H$ of the same form for the initial values of the coordinates. The author then writes

$$V=\int_0^t 2T\,dt,$$

an equation, the form of which implies that T is expressed as a function of the time and of the constants of integration a, b, c, a', b', c'. The method of the calculus of variations leads to the equation

$$\delta V=m(x'\delta x+y'\delta y+z'\delta z)-m(a'\delta a+b'\delta b+c'\delta c)+t\delta H,$$

to understand which, it should be remarked that the coordinates x, y, z, and the velocities x', y', z', being functions of t and of a, b, c, a', b', c', then V is, in the first instance, given as a function of these quantities. But x, y, z being functions of a, b, c, a', b', c', t, we may conversely consider a', b', c' as functions of x, y, z, a, b, c, t, and thus V becomes a function of x, y, z, a, b, c, t. In like manner H is a function of x, y, z, a, b, c, t, and, eliminating t, we have V a function of x, y, z, a, b, c, H, which is the form in which in the last equation V is considered to be expressed. The equation then gives

$$\frac{dV}{dx}= mx', \frac{dV}{dy}= my', \frac{dV}{dz}= mz',$$

$$\frac{dV}{da}=-ma', \frac{dV}{db}=-mb', \frac{dV}{dc}=-mc',$$

$$\frac{dV}{dH}=t;$$

and, considering V as a known function of x, y, z, a, b, c, H, the elimination of H gives a set of equations which are in fact the integral equations of the problem, viz., the first three equations and the last equation give equations containing x, y, z, x', y', z', t and a, b, c, that is, the intermediate integrals; the second three equations and the last equation, give equations containing $x, y, z, t, a, b, c, a', b', c'$, that is, the final integrals.

The function V satisfies the two partial differential equations

$$\frac{1}{2m}\left\{\left(\frac{dV}{dx}\right)^2+\left(\frac{dV}{dy}\right)^2+\left(\frac{dV}{dz}\right)^2\right\}=U+H$$

$$\frac{1}{2m}\left\{\left(\frac{dV}{da}\right)^2+\left(\frac{dV}{db}\right)^2+\left(\frac{dV}{dc}\right)^2\right\}=U_0+H;$$

which, if they could be integrated, would give V as a function of x, y, z, a, b, c, H, and thus determine the motion of the system.

23. Hamilton's principal function S.—This is connected with the function V by the equation

$$V=tH+S;$$

or, what is the same thing, the new principal function S is defined by the equation

$$S=\int_0^t (T+U)dt;$$

but S is considered (not like V as a function of x, y, z, a, b, c; H, but) as a function of x, y, z, a, b, c, t. The expression for the variation of S is

$$\delta S=-H\delta t+m(x'\delta x+y'\delta y+z'\delta z)-m(a'\delta a+b'\delta b+c'\delta c)$$

which is equivalent to the system

$$\frac{dS}{dx}= mx', \frac{dS}{dy}= my', \frac{dS}{dz}= mz',$$

$$\frac{dS}{da}=-ma', \frac{dS}{db}=-mb', \frac{dS}{dc}=-mc',$$

$$\frac{dS}{dt}=-H;$$

the first three and the second three of which give, respectively, the intermediate and the final integrals; the last equation leads only to the expression of the supernumerary constant H in terms of the initial coordinates a, b, c, and it may be omitted from the system.

The function S satisfies the partial differential equations

$$\frac{dS}{dt}+\frac{1}{2m}\left\{\left(\frac{dS}{dx}\right)^2+\left(\frac{dS}{dy}\right)^2+\left(\frac{dS}{dz}\right)^2\right\}=U,$$

$$\frac{dS}{dt}+\frac{1}{2m}\left\{\left(\frac{dS}{da}\right)^2+\left(\frac{dS}{db}\right)^2+\left(\frac{dS}{dc}\right)^2\right\}=U_0;$$

which, if they could be integrated, would give S as a function of x, y, z, a, b, c, t, and thus determine the motion of the system.

24. Hamilton's form of the equations of motion.—This is in fact the form obtained by carrying out the idea of introducing into the differential equations, in the place of the differential coefficients of the coordinates, the derived functions (with respect to these differential coefficients) of the *vis viva* function T. Taking η to denote any one of the series of coordinates, then the original system may be denoted by

$$\frac{d}{dt}\frac{d\mathrm{T}}{d\eta'}-\frac{d\mathrm{T}}{d\eta}=\frac{d\mathrm{U}}{d\eta},$$
$$\vdots$$

(U is the force function taken with a contrary sign to that of Lagrange), and writing in like manner ϖ to denote any one of the new variables connected with the coordinates η by the equations

$$\frac{d\mathrm{T}}{d\eta'}=\varpi,$$
$$\vdots$$

then T, in its original form, is a function of $\eta, \ldots \eta', \ldots$, homogeneous of the second order as regards the differential coefficients $\eta' \ldots$; and, consequently, these being linear functions (without constant terms) of the new variables ϖ, the *vis viva* function T can be expressed as a function of $\eta, \ldots \varpi, \ldots$, homogeneous of the second order as regards the variables $\varpi, \ldots$ And when T has been thus expressed, the equations of motion take the form

$$\frac{d\eta}{dt}=\frac{d\mathrm{H}}{d\varpi},\ \frac{d\varpi}{dt}=-\frac{d\mathrm{T}}{d\eta}+\frac{d\mathrm{U}}{d\eta},$$
$$\vdots \qquad \vdots$$

which is the required transformation. The force function U is independent of the differential coefficients $\eta', \ldots$ and, consequently, of the variables $\varpi, \ldots$, hence, writing $\mathrm{H}=\mathrm{T}-\mathrm{U}$, the equations take the form

$$\frac{d\eta}{dt}=\frac{d\mathrm{H}}{d\varpi},\ \frac{d\varpi}{dt}=-\frac{d\mathrm{H}}{d\eta},*$$
$$\vdots \qquad \vdots$$

which correspond to the condensed form obtained by writing $\mathrm{T}-\mathrm{V}=\mathrm{R}$ in Lagrange's equations. It is hardly necessary to remark that H is to be considered as a given function of $\eta, \ldots \varpi, \ldots$, viz., it is what $\mathrm{T}-\mathrm{U}$ becomes when the differential coefficients $\eta', \ldots$ are replaced by their values in terms of the new variables $\varpi, \ldots$

25. I have, for greater simplicity, explained the theory of the functions V and S in reference to a very special form of the equations of motion; but the theory is, in fact, applicable to any form whatever of these equations; and, as regards the function V, is in the first memoir examined in detail with reference to Lagrange's general form of the equations of motion. The function S is considered at the end of the memoir in reference only to the special form. The new form of the equations of motion is first established in the second memoir, and the theory of the functions V and S is there considered in reference to this form. The author considers also another function Q, which, when the matter is looked at from a somewhat more general point of view, is not really distinct from the function S.

* I find it stated in a note to M. Houel's 'Thèse sur l'intégration des équations différentielles de la Mécanique,' Paris, 1855, that this form of the equations of motion had been previously employed in an *unpublished* memoir by Cauchy, written in 1831.

26. The first memoir contains applications of the method to the problem of two bodies, and the problem of three or more bodies, and researches in reference to the approximate integration of the equations of motion by the separation of the function V into two parts, one of them depending on the principal forces, the other on the disturbing forces. The method, or one of the methods, given for this purpose, involves the consideration of the variation of the arbitrary constants, but it is not easy to single out any precise results, or explain their relation to the results of Lagrange and Poisson. The like remark applies to the investigations contained in Nos. 7 to 12 of the second memoir, but it is important to consider the theory described in the heading of No. 13, as "giving formulæ for the variation of elements more analogous to those already known." The function H is considered as consisting of two parts, one of them being treated as a disturbing function; the equations of motion assume therefore the form

$$\frac{d\eta}{dt}=\frac{dH}{d\varpi}+\frac{d\Upsilon}{d\varpi},\ \frac{d\varpi}{dt}=-\frac{dH}{d\eta}-\frac{d\Upsilon}{d\eta}$$

(I have written H, Υ instead of the author's H_1, H_2). The terms involving Υ are in the first instance neglected, and it is assumed that the integrals of the resulting equations are presented in the form adopted by Poisson, viz., the constants of integration a, b, &c., are considered as given in terms of t, and of the two sets of variables $\eta, \ldots$ and $\varpi, \ldots$; the integrals are then extended to the complete equations by the method of the variation of the elements. The resulting expressions are the same in form as those of Poisson, viz.:—

$$\frac{da}{dt}=(a,\, b)\frac{d\Upsilon}{db}+\ldots$$

where

$$(a,\, b)=\frac{\partial(a, b)}{\partial(\eta, \varpi)}+\ldots$$

if, for shortness,

$$\frac{\partial(a,\, b)}{\partial(\eta,\, \varpi)}=\frac{da}{d\eta}\frac{db}{d\varpi}-\frac{db}{d\eta}\frac{da}{d\varpi}$$

and conversely the values of $\frac{d\Upsilon}{da}$, &c. in terms of $\frac{da}{dt}$, &c. might have been exhibited in a form such as that of Lagrange. The expressions (a, b), considered as functional symbols, have the same meanings as in the theories of Poisson and Lagrange; and, as in these theories, the differential coefficient of (a, b) with respect to the time, vanishes, or (a, b) is a function of the elements only.

27. It is to be observed that the disturbing function Υ is not necessarily in the same problem identical with the disturbing function Ω of Lagrange and Poisson (indeed, in any problem, the separation of the forces into principal forces and disturbing forces is an arbitrary one). Sir W. R. Hamilton, in the second memoir, gives a very beautiful application of his theory to the problem of three or more bodies, which has the peculiar advantage of making the motion of all the bodies depend upon one and the same disturbing function*. This disturbing function contains (as in the last-mentioned

* Lagrange has given formulæ for the determination of the motion of three or more bodies referred to their common centre of gravity by means of one and the same disturbing function. In Sir W. R. Hamilton's theory there is one central body to which all the others

general formulæ) both sets of variables, and the consequence is that, as the author remarks, the varying elements employed by him are essentially different from those made use of in the theories of Lagrange and Poisson; the velocities cannot, in his theory, be obtained by differentiating the coordinates as if the elements were constant. The investigation applies to the case where the attracting force is any function whatever of the distance, and the six elements ultimately adopted form a canonical system.

28. The precise relation of Sir W. R. Hamilton's form of the equations of motion to that of Lagrange's, is best seen by considering Lagrange's equations, not as a system of differential equations of the second order between the coordinates and the time t, but as a system of twice as many differential equations of the first order between the coordinates, their differential coefficients treated as a new system of variables, and the time. It will be convenient to write $-\mathrm{U}$, instead of Lagrange's force-function V, and (to conform to the usage of later writers who have treated the subject in the most general manner) to represent the coordinates by $q, \ldots$, their differential coefficients by $q', \ldots$, and the new variables which enter into the Hamiltonian form by $p, \ldots$; then the Lagrangian system will be

$$\begin{array}{ll} \dfrac{dq}{dt}=q', & \dfrac{d}{dt}\dfrac{d\mathrm{T}}{dq'}-\dfrac{d\mathrm{T}}{dq}=\dfrac{d\mathrm{U}}{dq}; \\ \vdots & \vdots \end{array}$$

or putting $\mathrm{T}+\mathrm{U}=\mathrm{Z}$ (this is the same as Lagrange's substitution, $\mathrm{T}-\mathrm{V}=\mathrm{R}$), the system becomes

$$\begin{array}{ll} \dfrac{dq}{dt}=q', & \dfrac{d}{dt}\dfrac{d\mathrm{Z}}{dq'}=\dfrac{d\mathrm{Z}}{dq}, \\ \vdots & \vdots \end{array}$$

while the Hamiltonian system is

$$\begin{array}{ll} \dfrac{dq}{dt}=\dfrac{d\mathrm{T}}{dp}, & \dfrac{dp}{dt}=-\dfrac{d\mathrm{T}}{dq}+\dfrac{d\mathrm{U}}{dq}; \\ \vdots & \vdots \end{array}$$

or putting as before $\mathrm{T}-\mathrm{U}=\mathrm{H}$, the system is

$$\begin{array}{ll} \dfrac{dq}{dt}=\dfrac{d\mathrm{H}}{dp}, & \dfrac{dp}{dt}=-\dfrac{d\mathrm{H}}{dq}; \\ \vdots & \vdots \end{array}$$

where, in the Lagrangian systems, T and U, and consequently Z, are given functions of a certain form of $t, q, \ldots q', \ldots$, and in like manner, in the Hamiltonian system, T and U, and consequently H, are given functions of a certain form of $t, q, \ldots p \ldots$ The generalisation has since been made (it is not easy to say precisely when first made) of considering Z as standing for any function whatever of $t, q, \ldots q', \ldots$, and in like manner of considering H as standing for any function whatever of $t, q, \ldots p, \ldots$ It is to be noticed that in Sir W. R. Hamilton's memoir, the demonstration which is given of the transformation from Lagrange's equations to the new form depends essentially on the special form of the function T as a homogeneous function of the second order in regard to the differential coefficients of the coordinates; indeed the transformation itself, as regards the actual value of the new function T (=T expressed in terms of the new variables), which enters into the

are referred. The method of Sir W. R. Hamilton is made use of in M. Houel's 'Thèse d'Astronomie: Application de la Méthode de M. Hamilton au Calcul des Perturbations de Jupiter.'—Paris, 1855.

transformed equations, depends essentially upon the special form just referred to of the function T, although, as will be seen in the sequel, there is a like transformation applying to the most general form of the function T.

29. In the greater part of what has preceded, and especially in the abovementioned substitutions $T+U=Z$ and $T-U=H$, it is of course assumed that the force function U exists; when there is no force function these substitutions cannot be made, but the forms corresponding to the untransformed forms in T and U are as follows, viz. the Lagrangian form is

$$\frac{dq}{dt}=q', \quad \frac{d}{dt}\frac{dT}{dq'}-\frac{dT}{dq}=Q,$$

and the Hamiltonian form is

$$\frac{dq}{dt}=\frac{dT}{dp}, \quad \frac{dp}{dt}=-\frac{dT}{dq}+Q;$$

that is, the only difference is, that the functions Q, instead of being the differential coefficients with respect to the variables $q\ldots$ of one and the same force function U, are so many separate and distinct functions of the variables $q,\ldots$, or more generally of the variables $q,\ldots p,\ldots$ of both sets.

30. Jacobi's letter of 1836.—This is a short note containing a mere statement of two results. The first is as follows, viz. the equations for the motion of a point *in plano* being taken to be

$$\frac{d^2x}{dt^2}=\frac{dU}{dx}, \quad \frac{d^2y}{dt^2}=\frac{dU}{dy},$$

where U is a function x, y without t; one integral is the equation of *vis viva* $\frac{1}{2}(x'^2+y'^2)=U+h$. Assume that another integral is $a=F(x, y, x', y')$, then x', y' will in general be functions of x, y, a, h, and considering them as thus expressed, it is stated that not only $x'dx+y'dy$ will be an exact differential, but its differential coefficients with respect to a, h will be so likewise, and the remaining integrals are

$$b=\int\left(\frac{dx'}{da}dx+\frac{dy'}{da}dy\right),$$

$$t+T=\int\left(\frac{dx'}{dh}dx+\frac{dy'}{dh}dy\right),$$

a theorem, the relation of which to the general subject will presently appear.

The second result does not relate to the general subject, but I give it in a note for its own sake*.

31. Poisson's memoir of 1837.—This contains investigations suggested by

* Jacobi imagines a point *without mass* revolving round the sun and disturbed by a planet moving in a circular orbit, which is taken for the plane of x, y; the coordinates of the point are x, y, z, those of the planet $a' \cos n't$, $a' \sin n't$, m' is the mass of the planet, M the mass of the sun; then we have accurately

$$\tfrac{1}{2}\left\{\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2+\left(\frac{dz}{dt}\right)^2\right\}-n'\left(x\frac{dy}{dt}-y\frac{dx}{dt}\right)=$$

$$\frac{M}{(x^2+y^2+z^2)^{\frac{1}{2}}}+m'\left\{\frac{1}{(x^2+y^2+z^2-2a'(x\cos n't+y\sin n't)+a'^2)^{\frac{1}{2}}}-\frac{a'^3}{x\cos n't+y\sin n't}\right\}+\text{Const.}$$

which Jacobi suggests might be found useful in the lunar theory. The point being without mass, means only that it is considered as not disturbing the circular motion of the planet; the problem is properly a case of the problem of two centres, viz. one centre is fixed, and the other one revolves round it in a circle with a uniform velocity.

Sir W. R. Hamilton's memoir, and relating to the aid to be derived from a system of given integral equations (equal in number to the coordinates) in the determination of the principal function V. The equations $\frac{dV}{dx}=mx'$, &c. give $dV=m(x'dx+y'dy+z'dz)$, or in the case of a system of points, $dV=\Sigma m(x'dx+y'dy+z'dz)$. If the points, instead of being free, are connected together by any equations of condition, then, by means of these equations, the coordinates x, y, z of the different points and their differential coefficients x', y', z', can be expressed as functions of a certain number of independent variables ϕ, ψ, θ, &c., and of their differential coefficients ϕ', ψ', θ', &c.; dV then takes the form $dV=Xd\phi+Yd\psi+Zd\theta+$ .. where X, Y, Z are functions of $\phi, \psi, .. \phi', \psi', ...$ Imagine now a system of integrals (one of them the equation of *vis viva*) equal in number to the independent variables ϕ, ψ, θ ..; then, by the aid of these equations, ϕ', ψ', θ' .., and, consequently, X, Y, Z .. can be expressed as functions (of the constants of integration and) of the variables $\phi, \psi, \theta, ...$ Hence, attending only to the variables, $dV=Xd\phi+Yd\psi+Zd\theta+$ .. is a differential expression involving only the variables ϕ, ψ, θ ..; but, as Poisson remarks, this expression is not in general a complete differential. In the cases in which it is so, V can of course be obtained directly by integrating the differential expression, viz. the function so obtained is in value, but not in form, Sir W. R. Hamilton's principal function V, for, with him, V is a function of the coordinates, and of a particular set of the constants of integration, viz. the constant of *vis viva* h, and the initial values of the coordinates. Poisson adds the very important remark, that V being determined by his process as above, then h being the constant of *vis viva*, and the constants of the other given integral equations being e, f, &c., the remaining integrals of the problem are*

$$\frac{dV}{dh}=t+\tau, \frac{dV}{de}=l, \frac{dV}{df}=m, ..$$

where $\tau, l, m, ..$ are new arbitrary constants. But, as before remarked, the expression for dV is not always a complete differential. Poisson accordingly inquires into and determines (but not in a precise form) the conditions which must be satisfied, in order that the expression in question may be a complete differential. He gives, as an example, the case of the motion of a body in space under the action of a central force; and, secondly, the case considered in Jacobi's letter of 1836, which he refers to, viz., here $dV=x'dx+y'dy$, and when the two integral equations are one of them, the equation of *vis viva* $\frac{1}{2}(x'^2+y'^2)=U+h$, and the other of them any integral equation $a=F(x, y, x', y')$ whatever (subject only to the restriction that a is not a function of $x, y, x'^2+y'^2$, the necessity of which is obvious) the condition is satisfied *per se*, and, consequently, $x'dx+y'dy$ is a complete differential, and its integral gives (in value, although as before remarked not iu form) the principal function V; and such value of V gives the two integral equations obtained in Jacobi's letter.

32. Jacobi's note of the 29th of November, 1836, 'On the Calculus of Variations, and the Theory of Differential Equations.'—The greater part of this note relates to the differential equations which occur in the calculus of

* Poisson writes $\frac{dV}{dh}=-t+\epsilon$; there seems to be a mistake as to the sign of h running through the memoir. Correcting this, and putting $-\tau$ for ϵ, we have the formula $\frac{dV}{dh}=t+\tau$ given in the text.

variations, including, indeed, the differential equations of dynamics, but which belong to a different field of investigation. The latter part of the note relates more immediately to the differential equations of dynamics. The author remarks, that, in any dynamical problem of the motion of a single particle for which the principle of *vis viva* holds good, if, besides the integral of *vis-viva*, there is given any other integral, the problem is reducible to the integration of an ordinary differential equation of two variables, and that it is always possible to integrate this equation, or at least *discover by a precise and general rule the factor which renders it integrable.* This would seem to refer to Jacobi's researches on the theory of the ultimate multiplier, but the author goes on to refer to a preceding communication to the Academy of Paris (the before-mentioned letter of 1836), which does not belong (or, at least, does not obviously belong) to this theory. He speaks also of a class of dynamical problems, viz. that of the motion of a system of bodies which mutually attract each other, and which may besides be acted upon by forces in parallel lines, or directed to fixed centres, or even to centres the motion of which is given; and, he remarks, in the solution of such a problem, the system of differential equations being in the first instance of the order $2n$ (that is, being a system admitting of $2n$ arbitrary constants), then if one integral is known, it is possible by a proper choice of the quantities selected for variables to reduce the system to the order $2n-2$. If another integral is known, the equation may in like manner be reduced to a system of the order $2n-4$, and so on until there are no more equations to be integrated; and thus the operations to be effected depend only upon quadratures. All this seems to refer to researches of Jacobi, which, so far as I am aware, have not hitherto been published. The results correspond with those recently obtained by Bour, *post*, Nos. 66 and 67.

33. Jacobi's memoir of 1837.—Jacobi refers to the memoirs of Sir W. R. Hamilton, and he reproduces, in a slightly different form, the investigation of the fundamental property of the principal function S. The case considered is that of a system of n particles, the coordinates of which are connected together by any number of equations; but it will be sufficient here to attend to the case of a single free particle. The equations of motion are assumed to be

$$m\frac{d^2x}{dt^2}=\frac{dU}{dx},\ m\frac{d^2y}{dt^2}=\frac{dU}{dy},\ m\frac{d^2z}{dt^2}=\frac{dU}{dz}.$$

But U is considered as being a function of x, y, z and of the time t, that is, it is assumed that the condition of *vis viva* is not of necessity satisfied. The definition of the function S is

$$S+\int_0^t\left[U+\tfrac{1}{2}m(x'^2+y'^2+z'^2)\right]dt,\text{ which,}$$

when the equation of *vis viva* is satisfied, that is, when $T=\frac{1}{2}m(x'^2+y'^2+z'^2)$ $=U+h$, agrees with Sir W. R. Hamilton's definition $S=2\int_0^t Udt+ht$. The function S is considered as being, by means of the integral equations assumed as known, expressed as a function of t, of the coordinates x, y, z, and of their initial values a, b, c. And then it is shown that S satisfies the equations

$$\frac{dS}{dx}=mx',\quad \frac{dS}{dy}=my',\quad \frac{dS}{dz}=mz',$$
$$\frac{dS}{da}=-ma',\ \frac{dS}{db}=-mb',\ \frac{dS}{dc}=-mc';$$

so that the intermediate and final integrals are expressed by means of the principal function S.

34. But Jacobi proceeds, "the definition assumes the integration of the differential equations of the problem. The results, therefore, are only interesting in so far as they have reduced the system of integral equations into a remarkable form. We may, however, define the function S in a quite different and *very much more general* manner." And then, attending only to the case of a system of free particles, he gives a definition, which, in the case of a single particle, is as follows:—

Jacobi's principal function S.—The equations of motion being as before

$$\frac{d^2x}{dt^2}=m\frac{dU}{dx},\ \frac{d^2y}{dt^2}=m\frac{dU}{dy},\ \frac{d^2z}{dt^2}=m\frac{dU}{dz}$$

(where U is in general a function of x, y, z and t), then S is defined to be a *complete* solution of the partial differential equation

$$\frac{dS}{dt}+\frac{1}{2m}\left\{\left(\frac{dS}{dx}\right)^2+\left(\frac{dS}{dy}\right)^2+\left(\frac{dS}{dz}\right)^2\right\}=U.$$

A complete solution, it will be recollected, means a solution containing as many arbitrary constants as there are independent variables in the partial differential equations; in the present case, therefore, four arbitrary constants. But one of these constants may be taken to be a constant attached to the function S by mere addition, and which disappears from the differential coefficients, and it is only necessary to attend to the other three arbitrary constants. S is consequently a function of t, x, y, z, and of the arbitrary constants α, β, γ, satisfying the partial differential equation. And this being so, it is shown that the integrals of the problem are

$$\frac{dS}{dx}=mx',\ \frac{dS}{dy}=my',\ \frac{dS}{dz}=mz',$$

$$\frac{dS}{d\alpha}=\lambda,\ \frac{dS}{d\beta}=\mu,\ \frac{dS}{d\gamma}=\nu\,;$$

where λ, μ, ν are any other arbitrary constants, viz., the first three equations give the intermediate integrals, and the last three equations give the final integrals of the problem.

Jacobi proceeds to give an analogous definition of the principal function V as follows:—

35. Jacobi's principal function V.—First, when the condition of *vis viva* is satisfied. Here V is a complete solution of the partial differential equation

$$\frac{1}{2m}\left\{\left(\frac{dV}{dx}\right)^2+\left(\frac{dV}{dy}\right)^2+\left(\frac{dV}{dz}\right)^2\right\}=U+h,$$

where h is the constant of *vis viva*. The partial differential equation contains only three independent variables; and since as before one of the constants of the complete solution may be taken to be a constant attached to V by mere addition, and which disappears from the differential coefficients, we may consider V as a function of t, x, y, z, and of the two constants of integration α and β. But V will of course also contain the constant h, which enters into the partial differential equation. The integrals of the problem are then shown to be

$$\frac{dV}{dx}=mx', \frac{dV}{dy}=my', \frac{dV}{dz}=mz',$$
$$\frac{dV}{dh}=t+\tau, \frac{dV}{d\alpha}=\lambda, \quad \frac{dV}{d\beta}=\mu,$$

where τ, λ, μ are new arbitrary constants.

36. Jacobi's principal function V.—Secondly, when the equation of *vis viva* is not satisfied. Here U contains the time t, and we have no such equation as $T=U+h$, but along with the coordinates x, y, z there is introduced a new variable H, and V is defined to be a complete integral of the partial differential equation

$$\frac{1}{2m}\left\{\left(\frac{dV}{dx}\right)^2+\left(\frac{dV}{dy}\right)^2+\left(\frac{dV}{dz}\right)^2\right\}=U+H;$$

where, in the expression for U, it is assumed that t is replaced by $\frac{dV}{dH}$. There are, consequently, four independent variables, and a complete solution must contain, exclusively of the constant attached to V by mere addition, and which disappears from the differential coefficients, three arbitrary constants α, β, γ. The integral equations are shown to be

$$\frac{dV}{dx}=mx', \frac{dV}{dy}=my', \frac{dV}{dz}=mz',$$
$$\frac{dV}{d\alpha}=\lambda, \quad \frac{dV}{d\beta}=\mu, \quad \frac{dV}{d\gamma}=\nu,$$
$$\frac{dV}{dH}=t;$$

where λ, μ, ν are arbitrary constants, viz., eliminating H from the first three equations by the assistance of the last equation, we have the intermediate integrals; and eliminating H from the second three equations by the assistance of the last equation, we have the final integrals. The substitution of the above values $\frac{dV}{dx}$, &c., in the partial differential equation gives $T=U+H$, that is, $H(=T-U)$ is that function which, when the condition of *vis viva* is satisfied, becomes equal to h, the constant of *vis viva*.

Jacobi's extension of the theory to the case where the condition of *vis viva* is not satisfied, appears to have attracted very little attention; it is indeed true, as will be noticed in the sequel, that this general case can be reduced to the particular one in which the condition of *vis viva* is satisfied, but there is not it would seem any advantage in making this reduction; the formulæ for the general case are at least quite as elegant as those for the particular case.

37. Jacobi, after considering some particular dynamical applications, proceeds to apply the theory developed in the first part of the memoir to the general subject of partial differential equations; the differential equations of a dynamical problem lead to a partial differential equation, a complete solution of which gives the integral equations. Conversely, the integral equations give the complete solution of the partial differential equation, and applying similar considerations to any partial differential equation of the first order whatever, it is shown (what, but for Cauchy's memoir of 1819, which Jacobi was not acquainted with*, would have been a new theorem)

* Jacobi refers to Lagrange's 'Leçons sur la Théorie des Fonctions,' and to a memoir by Pfaff in the 'Berlin Transactions' for 1814, as containing, so far as he was aware, every-

that the solution of the partial differential equation depends on the integration of a single system of partial differential equations. The remainder of the memoir is devoted to the discussion of this theory and of the integration of the Pfaffian system of ordinary differential equations, a system which is also treated of in Jacobi's memoir of 1844, 'Theoria Novi Multiplicatoris,' &c. I take the opportunity of referring here to a short note by Brioschi, 'Intorno ad una Proprietà delle Equazione alle Derivate Parziale del Primo Ordine,' Tortolini, t. vi. pp. 426–429 (1855), where the theory of the integration of a partial differential equation of the first order is presented under a singularly elegant form.

38. Jacobi's note of 1837, 'On the Integration of the Differential Equations of Dynamics.'—Jacobi remarks that it is possible to derive from Lagrange's form of the equations of motion an important profit for the integration of these equations, and he refers to his communication of the 29th of November 1839 to the Academy of Berlin, and to his former note to the Academy of Paris. He proceeds to say, that whenever the condition of *vis viva* holds good, he had found that it was possible in the integration of the equations of motion to follow a course such that each of the given integrals successively lowers by two unities the order of the system; and that the like theorem holds good when the condition of *vis viva* is not satisfied, that is, when the force function involves the time (this seems to be a restatement, in a more general form, of the theorems referred to in the note of the 29th of November 1836 to the Academy of Berlin); and he mentions that he had been, by his researches on the theory of numbers, led away from composing an extended memoir on the subject. The note then passes on to other subjects, and it concludes with two theorems, which are given without demonstration as extracts from the intended work he had before spoken of. These theorems are in effect as follows:—

I. Let

$$m\frac{d^2x}{dt^2}=\frac{dU}{dx},\ m\frac{d^2y}{dt^2}=\frac{dU}{dy},\ m\frac{d^2z}{dt^2}=\frac{dU}{dz},\ \&c.$$

be the $3n$ differential equations of the motion of a free system, and

$$\tfrac{1}{2}\Sigma m(x'^2+y'^2+z'^2)dt=U+h,$$

the equation of *vis viva*.

Let V be a complete solution of the partial differential equation

$$\tfrac{1}{2}\Sigma\frac{1}{m}\left\{\left(\frac{dV}{dx}\right)^2+\left(\frac{dV}{dy}\right)^2+\left(\frac{dV}{dz}\right)\right\}=U+h,$$

that is, a solution containing, besides the constant attached to V by mere addition, $3n-1$ constants $a(a_1, a_2 \ldots a_{3n-1})$, then first the integral equations are

$$\frac{dV}{da}=\beta, \ldots \quad \frac{dV}{dh}=t+\tau;$$

where $\beta(\beta_1, \beta_2 \ldots \beta_{3n-1})$ and τ are new arbitrary constants: this is in fact the theorem already quoted from Jacobi's memoir of 1837, and it is in the present place referred to as an easy generalisation of Sir W. R. Hamilton's

thing essential which was known in reference to the integration of partial differential equations of the first order; he refers also to his own memoir 'Ueber die Pfaffsche Methode,' &c., Crelle, t. ii. pp. 347–358 (1827), as presenting the method in a more symmetrical and compendious form, but without adding to it anything essentially new.

formulæ. But Jacobi proceeds (and this is given as entirely new) that the disturbed equations being

$$m\frac{d^2x}{dt^2}=\frac{dU}{dx}+\frac{d\Omega}{dx},\ m\frac{d^2y}{dt^2}=\frac{dU}{dy}+\frac{d\Omega}{dy},\ m\frac{d^2z}{dt^2}=\frac{dU}{dz}+\frac{d\Omega}{dz},$$

then the equations for the variations of the above system of arbitrary constants are

$$\frac{da}{dt}=\ \frac{d\Omega}{d\beta},\dots\frac{dh}{dt}=\ \frac{d\Omega}{d\tau},$$

$$\frac{d\beta}{dt}=-\frac{d\Omega}{da},\dots\frac{d\tau}{dt}=-\frac{d\Omega}{dh};$$

so that the constants form (I think the term is here first introduced) a canonical system.

Jacobi observes, that in the theory of elliptic motion, certain elements which he mentions, form a system of canonical elements, and he remarks, that since one complete solution of a partial differential equation gives all the others, the theorem leads to the solution of another interesting problem, viz. "Given one system of canonical elements, to find all the other systems." This is effected by means of the second theorem, which is as follows:—

II. Given the systems of differential equations between the variables $a(a_1, a_2 \dots a_m)$ and $b(b_1, b_2 \dots b_m)$

$$\frac{da}{dt}=-\frac{dH}{db},\dots\ \ \frac{db}{dt}=\frac{dH}{da},\dots$$

where H is *any function* of the variables $a,\dots$ and $b,\dots$; and let $\alpha(\alpha_1,\alpha_2\dots\alpha_m)$ and $\beta(\beta_1,\beta_2\dots\beta_m)$ be two new systems of variables connected with the preceding ones by the equations

$$\frac{d\psi}{da}=\beta,\dots\ \ \frac{d\psi}{da}=-b,\dots$$

where ψ is a function of $\alpha,\dots b,\dots$ without t or the other variables, then expressing H as a function of t and the new variables $\alpha,\dots$ and $\beta,\dots$, these last variables are connected together by equations of the like form with the original system, viz.:—

$$\frac{d\alpha}{dt}=-\frac{dH}{d\beta},\dots\ \ \frac{d\beta}{dt}=-\frac{dH}{d\alpha},\dots$$

Jacobi concludes with the remark, that other theorems no less general may be deduced by putting $\psi+\lambda\psi_1+\mu\psi_2+\dots$ instead of ψ, and eliminating the multipliers $\lambda, \mu,\dots$ by means of the equations $\psi_1=0, \psi_2=0,\dots$, and that the demonstrations of the theorems are obtained without difficulty.

39. Jacobi's note of the 21st of November, 1838.—Jacobi refers to a memoir by Encke in the Berlin 'Ephemeris' for 1837, 'über die Speciellen Störungen,' where expressions are given for the partial differential coefficients of the values in the theory of elliptic motion of the coordinates x, y, z and the velocities x', y', z' with respect to the elements; and he remarks, that if Encke's elements are replaced by a system of elements $\alpha, \beta, \gamma, \alpha', \beta', \gamma'$ which he mentions, connected with those of Encke by equations of a simple form, then considering first x, y, z, x', y', z' as given functions of t and the elements, and afterwards the elements $\alpha, \beta, \gamma, \alpha', \beta', \gamma'$ as given functions of t and x, y, z, x', y', z', there exists the remarkable theorem that the thirty-six partial differential coefficients $\frac{d\alpha}{dx}, \frac{d\beta}{dx}$, &c., and the thirty-six partial differential co-

efficients $\frac{dx}{da}, \frac{dx}{d\beta}$, &c. are equal to each other, or differ only in their sign, viz.

$$\frac{dx}{da}=-\frac{da'}{dx'}, \frac{dx}{da'}=\frac{da}{dx'}, \frac{dx'}{da}=\frac{da'}{dx}, \frac{\partial x'}{\partial a'}=-\frac{da}{dx};$$

thirty-six equations in all, viz. the pair a, a' of corresponding elements may be replaced by the pair β, β' or γ, γ': and then in each of the twelve equations y, y' or z, z' may be written instead of x, x'. The like applies to a system of constants which are the initial values of any system whatever of coordinates $p, \ldots$, and the initial values of the differential coefficients $q'=\frac{d\mathrm{T}}{dp}$, &c. of the force function T with respect to $p, \ldots$; *and for every system of elements which possess the property first mentioned, the formulæ for the variations assume the simplest possible form, inasmuch as the variation of each element is equal to a single partial differential coefficient of the disturbing function with the coefficient* $+1$ *or* -1, *as is known to be the case with the last-mentioned system of elements*; in other words, if $a, \ldots$ and $b, \ldots$ be a system of elements corresponding to each other in pairs, such that

$$\frac{dp}{da}=-\frac{db}{dq}, \frac{dp}{db}=\frac{da}{dq}, \frac{dq}{da}=\frac{db}{dp}, \frac{dq}{db}=-\frac{da}{dp}$$

(where a, b may be replaced by any other corresponding pair of elements, and p, q by any other corresponding pair of variables), then the elements $a, \ldots$ and $b, \ldots$ form a canonical system.

40. Jacobi's note of 1840 in the 'Comptes Rendus,' calls attention to the theorem contained in the passage quoted above from Poisson's memoir of 1808, a theorem which Jacobi characterizes as "la plus profonde découverte de M. Poisson," and as the theorem "le plus important de la Mécanique et de cette partie du calcul intégrale qui s'attache à l'intégration d'un système d'équations différentielles ordinaires"; and he proceeds, "le théorème dont il est question énoncé convenablement est le suivant—un nombre quelconque de points matérials étant tirés par des forces et soumis à des conditions telles que le principe des forces vives ait lieu, si l'on connait outre que l'intégrale fournie par ce principe deux autres intégrales, on en peut déduire une troisième d'une manière directe et sans même employer des quadratures. En poursuivant le même procédé on pourra trouver une quatrième une cinquième intégrale et en général on parviendra à cette manière à déduire des deux intégrales données toutes les intégrales ou ce qui revient au même l'intégration complète du problême. *Dans des cas particuliers on retombera sur une combinaison des intégrales déjà trouvées avant qu'on soit parvenu à toutes les intégrales du problême, mais alors les deux intégrales données jouissent des proprietés particulières dont on peut tirer un autre profit pour l'intégration des équations dynamiques proposées.* C'est ce qu'on verra dans un ouvrage auquel je travaille depuis plusieurs années et dont peut-être je pourrai bientôt faire commencer l'impression."

41. Liouville's addition to Jacobi's letter of 1840.—This contains the demonstration of a theorem similar to that given in Jacobi's letter of 1836, and Poisson's memoir of 1837, but somewhat more general; the system considered is a system of four differential equations of the first order:—

$$\frac{dx}{dt}=\lambda\frac{d\mathrm{U}}{dx'}, \frac{dx'}{dt}=-\lambda\frac{d\mathrm{U}}{dx}, \frac{dy}{dt}=\lambda\frac{d\mathrm{U}}{dy'}, \frac{dy'}{dt}=-\lambda\frac{d\mathrm{U}}{dy},$$

where U is a function of x, y, x', y', and λ is a function of x, y, x', y' and t.

One integral is $U=a$, and if there be another integral $V=b$ where V is a function of x, y, x', y' only, then x', y' being by means of these two integrals expressed as a function of x, y, a, b, it is shown that $x'dx+y'dy$ is an exact differential, and putting $\int(x'dx+y'dy)=\theta$, then that $\frac{d\theta}{db}=\beta$ is a new integral of the given equations; and in the case where λ is a function of t only, the remaining integral is $\frac{d\theta}{da}=\int\lambda dt+a$.

42. Binet's memoir of 1841 contains an exposition of the theory of the variation of the arbitrary constants as applied to the general system of equations

$$\frac{d}{dt}\frac{dF}{dx'}=\frac{dF}{dx'}+\lambda\frac{dL}{dx}+\mu\frac{dM}{dx}+\ldots$$
$$\vdots$$

where F is any function of t, and of the coordinates $x, y, z\ldots$ of the different points of the system, and of their differential coefficients x', y', z', &c., and $L=0$, $M=0$, &c. are any equations of equation between the coordinates $x, y, z, \ldots$ of the different points of the system, these equations may contain t, but they must not contain the differential coefficients $x', y', z', \ldots$ The form is a more general one than that considered by Lagrange and Poisson. The memoir contains an elegant investigation of the variations of the elements of the orbit of a body acted upon by a central force, the expressions for the variations being obtained in a canonical form; and there is also a discussion of the problem suggested in Poisson's report of 1830 on the manuscript work of Ostrogradsky.

43. Jacobi's note of 1842, in the 'Comptes Rendus,' announces the general principle (being a particular case of the theorem of the ultimate multiplier) stated and demonstrated in the memoir next referred to, and gives also the rule for the formation of the multiplier in the case to which the general principle applies.

44. Jacobi's memoir of 1842, 'De Motu Puncti singularis': the author remarks, that the greater the difficulties in the general integration of the equations of dynamics, the greater the care which should be bestowed on the examination of the dynamical problems in which the integration can be reduced to quadratures; and the object of the memoir is stated to be the examination of the simplest case of all, viz. the problems relating to the motion of a single point. The first section, entitled, 'De Extensione quadam Principii Virium vivarum,' contains a remark which, though obvious enough, is of considerable importance: the forces X, Y, Z which act upon a particle, may be such that $Xdx+Ydy+Zdz$ is not an exact differential, so that if the particle were free, there would be no force function, and the equations of motion would not be expressible in the standard form. But if the point move on a surface or a curve, then in the former case $Xdx+Ydy+Zdz$ will be reducible to the form $Pdp+Qdq$, which will be an exact differential if a single condition (instead of the three conditions which are required in the case of a free particle) be satisfied, and in the latter case it will be reducible to the form Pdp, which is, *per se*, an exact differential. In the case of a surface, the requisite transformation is given by the Hamiltonian form of the equations of motion, which Jacobi demonstrates for the case in hand; and then in the third section, with a view to its application to the particular case, he enumerates the general proposition "quæ pro novo principio mechanico haberi potest," which is as follows:—

"Consider the motion of a system of material points subjected to any

conditions, and let the forces acting on the several points in the direction of the axes be functions of the coordinates alone: if the determination of the orbits of the several points is reduced to the integration of a single differential equation of the first order between two variables, for this equation there may be found, by a general rule, a multiplier which will render it integrable by quadratures only."

And for the particular case the theorem is thus stated:—

"Given, three differential equations of the first order between the four quantities q_1, q_2, p_1, p_2,

$$dq_1 : dq_2 : dp_1 : dp_2 = \frac{d\mathrm{T}}{dp_1} : \frac{d\mathrm{T}}{dp_2} : -\frac{d\mathrm{T}}{dq_1} + \mathrm{Q}_1 : -\frac{d\mathrm{T}}{dq_2} + \mathrm{Q}_2,$$

in which $\mathrm{Q}_1, \mathrm{Q}_2$ are functions of q_1, q_2 only; and suppose that there are known two integrals α, β, and that by the aid of these $p_1, p_2, \frac{d\mathrm{T}}{dp_1}, \frac{d\mathrm{T}}{dp_2}$ are expressed by means of the quantities q_1, q_2 and the arbitrary constants α, β; there then remains to be integrated an equation of the first order, $\frac{d\mathrm{T}}{dp_1}dq_2 - \frac{d\mathrm{T}}{dp_2}dq_1 = 0$ between the quantities q_1, q_2, by which is determined the orbit of the point on the given surface: I say that the left-hand side of the equation multiplied by the factor

$$\frac{dp_1}{d\alpha}\frac{dp_2}{d\beta} - \frac{dp_2}{d\alpha}\frac{dp_1}{d\beta},$$

will be a complete differential, or will be integrable by quadratures alone," and the demonstration of the theorem is given. The remainder of the memoir, sections 4 to 7, is occupied by a very interesting discussion of various important special problems.

45. There is an important memoir by Jacobi, which, as it relates to a special problem, I will merely refer to, viz. the memoir 'Sur l'Elimination des Nœuds dans le problême des trois Corps,' Crelle, t. xxvii. pp. 115–131 (1843). The solution is made to depend upon six differential equations, all of them of the first order except one, which is of the second order, and upon a quadrature.

46. Jacobi's memoir of 1844, 'Theoria Novi Multiplicatoris,' &c.—This is an elaborate memoir establishing the definition and developing the properties of the "multiplier" of a system of ordinary differential equations, or of a linear partial differential equation of the first order, with applications to various systems of differential equations, and in particular to the differential equations of dynamics. The definition of the multiplier is as follows, viz. the multiplier of the system of differential equations

$$dx : dy : dz : dw \ldots = \mathrm{X} : \mathrm{Y} : \mathrm{Z} : \mathrm{W} \ldots$$

or of the linear partial differential equation of the first order

$$\mathrm{X}\frac{df}{dx} + \mathrm{Y}\frac{df}{dy}\mathrm{Z}\frac{df}{dz} + \mathrm{W}\frac{df}{dw} + \ldots = 0$$

is a function M, such that

$$\frac{d\mathrm{MX}}{dx} + \frac{d\mathrm{MY}}{dy} + \frac{d\mathrm{MZ}}{dz} + \frac{d\mathrm{MW}}{dw} + \ldots = 0.$$

One of the properties of the multiplier is that contained in the theorem of the ultimate multiplier, viz. that when all the integrals (except one) of the system of partial differential equations are known, and the system is thereby

reduced to a single differential equation between two variables, then the multiplier (in the ordinary sense of the word) of this last equation is $M\nabla$, where M is the multiplier of the system, and ∇ is a given derivative of the known integrals, so that the multiplier of the system being known, the integration of the last differential equation is reduced to a mere quadrature. To explain the theorem more particularly, suppose that the system of given integrals, that is, all the integrals (except one) of the system are represented by $p=\alpha$, $q=\beta$, ..., and let u, v be any two functions whatever of the variables, so that $p, q, \ldots u, v$ are in number equal to the system $x, y, z, w, \ldots$ then if

$$\mathrm{X}\frac{du}{dx}+\mathrm{Y}\frac{du}{dy}+\mathrm{Z}\frac{du}{dz}+\mathrm{W}\frac{du}{dw}+\ldots=\mathrm{U}$$

$$\mathrm{X}\frac{dv}{dx}+\mathrm{Y}\frac{dv}{dy}+\mathrm{Z}\frac{dv}{dz}+\mathrm{W}\frac{dv}{dw}+\ldots=\mathrm{V},$$

the last differential equation takes the form

$$\mathrm{U}dv-\mathrm{V}du=0,$$

where it is assumed that U and V are, by the assistance of the given integrals, expressed as functions of u, v and the constants of integration. The multiplier of the last-mentioned equation is $M\nabla$, where M is the multiplier of the system, and ∇ may be expressed in either of the two forms

$$\nabla=\frac{\partial(x,y,z,w,\ldots.)}{\partial(\alpha,\beta,\ldots.u,v)}$$

and

$$\nabla=\left\{\frac{\partial(p,q,\ldots.u,v)}{\partial(x,y,z,w,\ldots)}\right\}^{-1};$$

where the symbols on the right-hand sides represent functional determinants; in the first form it is assumed that $x, y, z, w, \ldots$ are expressed as functions of $\alpha, \beta, \ldots u, v$, and in the second form that $p, q, \ldots u, v$ are expressed as functions of $x, y, z, w, \ldots$, but that ultimately $p, q, \ldots$ are replaced by their values in terms of the constants and u, v; the first of the two forms, from its not involving this transformation backwards, appears the more convenient.

47. I have thought it worth while to quote the theorem in its general form, but we may take for u, v any two of the original variables, and if, to fix the ideas, it is assumed that there are in all the four variables x, y, z, w, then the theorem will be stated more simply as follows:—given the system of differential equations

$$dx:dy:dz:dw=\mathrm{X}:\mathrm{Y}:\mathrm{Z}:\mathrm{W},$$

and suppose that two of the integrals are $p=\alpha$, $q=\beta$, the last equation to be integrated will be

$$\mathrm{W}dz-\mathrm{Z}dw=0,$$

where, by the assistance of the given integrals, W, Z are expressed as functions of z, w. And the multiplier of this equation is $M\nabla$, where M is the multiplier of the system, and ∇, attending only to the first of the two forms, is given by the equation

$$\nabla=\frac{\partial(x,y)}{\partial(\alpha,\beta)},$$

which supposes that x, y are expressed as functions of α, β, z, w.

48. Jacobi applies the theorem of the ultimate multiplier to the differential equations of dynamics, considered first in the unreduced Lagrangian form, where the coordinates are connected by any given system of equations of condition; secondly, in the reduced or ordinary Lagrangian form; and, thirdly, in the Hamiltonian form. The multiplier can be found for the first two forms, and the expressions obtained are simple and elegant; but, as regards the third form, there is a further simplification: the multiplier M of the system is equal to the unity, and the multiplier of the last equation is therefore equal to ∇. The two cases are to be distinguished in which t does not, or does enter into the equations of motion; in the latter case the theorem furnished by the principle of the ultimate multiple is the same as for the general case of a system, the multiplier of which is known, viz., the theorem is, given all the integrals except one, the remaining integral can be found by quadratures only. But in the former case, which is the ordinary one, including all the problems in which the condition of *vis viva* is satisfied, there is a further consequence deduced. In fact, the time t may be separated from the other variables, and the system of differential equations reduced to a system not involving the time, and containing a number of equations less by unity than the original system, and the theorem of the ultimate multiplier applies to this new system. But when the integrals of the new system have been obtained, the system may be completed by the addition of a single differential equation involving the time, and which is integrable by quadratures; the theorem consequently is, given all the integrals except two, these given integrals being independent of the time, the remaining integrals can be found by quadratures only. This is, in fact, the 'Principium generale mechanicum' of the memoir of 1842.

The last of the published writings of Jacobi on the subject of dynamics are the 'Auszug zweier Schreiben des Professors Jacobi an Herrn Director Hansen,' Crelle, t. xlii. pp. 12-31 (1851): these relate chiefly to Hansen's theory of ideal coordinates.

49. The very interesting investigations contained in several memoirs by Liouville ('Liouville,' t. xi. xii. and xiv., and the additions to the 'Connaissance des Temps' for 1849 and 1850) in relation to the cases in which the equations of motion of a particle or system of particles admit of integration, are based upon Jacobi's theory of the S function, that is, of the function which is the complete solution of a certain partial differential equation of the first order; the equation is given, in the first instance, in rectangular coordinates, and the author transforms it by means of elliptic coordinates or otherwise, and he then inquires in what cases, that is, for what forms of the force function, the equation is one which admits of solution. A more particular account of these memoirs does not come within the plan of the present report.

50. Desbove's memoir of 1848 contains a demonstration of the two theorems given in Jacobi's note of 1837, in the 'Comptes Rendus;' and, as the title imports, there is an application of the theory to the problem of the planetary perturbations; the author refers to the above-mentioned memoirs of Liouville as containing a solution of the partial differential equation on which the problem depends, and also to a memoir of his own relating to the problem of two centres, where the solution is also given; and from this he deduces the solution just referred to, and which is employed in the present memoir. Jacobi's theorem gives at once the formulæ for the variation of the arbitrary constants contained in the solution. The material thing is to determine the signification of these constants, which can of course be done by a comparison of the formulæ with the known formulæ of

elliptic motion; the author is thus led to a system of canonical elements similar to, but not identical with, those obtained by Jacobi.

51. Serret's two notes of 1848 in the 'Comptes Rendus.'—These relate to the theory of Jacobi's S function, that is, of the function considered as the complete solution of a given partial differential equation of the first order. In the first of the two notes, which relates to a single particle, the author gives a demonstration founded on a particular choice of variables, viz., those which determine orthotomic surfaces to the curve described by the moving point. The process appears somewhat artificial.

52. Sturm's note of 1848, in the 'Comptes Rendus,' relates to the theory of Jacobi's S function, that is, of this function considered as the complete solution of a given partial differential equation of the first order. The force function is considered as involving the time t, which, however, is no more than had been previously done by Jacobi.

53. Ostrogradsky's note of 1848.—This contains an important step in the theory of the forms of the equations of motion, viz..it is shown how, in the case where the force function contains the time, the equations of motion may be transformed from the form of Lagrange to that of Sir W. R. Hamilton. If, as before, the force function (taken with the contrary sign to that of Lagrange) is represented by U, then putting, as before, $\mathrm{T}+\mathrm{U}=\mathrm{Z}$ (the author writes V instead of Z), in the case under consideration Z will contain not only terms of the second order and terms of the order zero in the differential coefficients of the coordinates $q,\ldots$, but also terms of the first order, that is, Z will be of the form $\mathrm{Z}=\mathrm{Z}_2+\mathrm{Z}_1+\mathrm{Z}_0$, and putting $\mathrm{H}=\mathrm{Z}_2-\mathrm{Z}_0$, this new function H being expressed as a function of the coordinates $q,\ldots$ and of the new variables $p,\ldots$, then the equations of motion take the Hamiltonian form, viz.—

$$\frac{dq}{dt}=\frac{d\mathrm{H}}{dp},\ \frac{dp}{dt}=-\frac{d\mathrm{H}}{dq}.$$

In the theory of the transformation, as originally given by Sir W. R. Hamilton, $\mathrm{Z}_2=\mathrm{T}$, $\mathrm{Z}_1=0$, $\mathrm{Z}_0=\mathrm{U}$, and, consequently, $\mathrm{H}=\mathrm{Z}_2-Z_0=\mathrm{T}-\mathrm{U}$ as before.

54. Brassinne's memoir of 1851.—The author reproduces for the Lagrangian equations of motion

$$\frac{d}{dt}\frac{d\mathrm{Z}}{d\xi'}-\frac{d\mathrm{Z}}{d\xi}=0,$$

the demonstration of the theorem

$$\frac{d}{dt}\left(\delta\frac{d\mathrm{Z}}{d\xi'}\Delta\xi-\Delta\frac{d\mathrm{Z}}{d\xi'}\delta\xi+\ldots\right)=0;$$

and he shows that a similar theorem exists with regard to the system

$$-\frac{d^2}{dt^2}\frac{d\mathrm{Z}}{d\xi''}+\frac{d}{dt}\frac{dz}{d\xi'}-\frac{d\mathrm{Z}}{d\xi}=0;$$

and with respect to the corresponding system of the mth order. The system in question, which is, in fact, the general form of the system of equations arising from a problem in the calculus of variations, had previously been treated of by Jacobi, but the theorem is probably new. In conclusion, the author shows in a very elegant manner the interdependence

of the theorem relating to Lagrange's coefficients (a, b), and of the corresponding theorem for the coefficients of Poisson.

55. Bertrand's memoir of 1851, 'On the Integrals common to several Mechanical Problems,' is one of great importance, but it is not very easy to explain its relation to other investigations. The author remarks that, given the integral of a mechanical problem, it is in general a question admitting of determinate solution to find the expression for the forces; in other words, to determine the problem which has given rise to the integral; at least, this is the case when it is assumed that the forces are functions of the coordinates, without the time or the velocities; and he points out how the solution of the question is to be obtained. But, in certain cases, the method fails, that is, it leads to expressions which are not sufficient for the determination of the forces; these are the only cases in which the given integral can belong to several different problems; and the method shows the conditions necessary, in order that these cases may present themselves. It is to be remarked that the given integral must be understood to be one of an absolutely definite form, such for instance as the equations of the conservation of the motion of the centre of gravity or of areas, but not such as the equation of *vis viva*, which is a property common indeed to a variety of mechanical problems, but which involves the forces, and is therefore not the *same* equation for different problems. The author studies in particular the case where the system consists of a single particle; he shows, that when the motion is in a plane, the integrals capable of belonging to two or more different problems are two in number, each of them involving as a particular case the equation of areas. When the point moves on a surface, he arrives at the remarkable theorem—"In order that the equations of motion of a point moving on a surface may have an integral independent of the time, and common to two or more problems, it is necessary that the surface should be a surface of revolution, or one which is developable upon a surface of revolution." When the condition is satisfied, he gives the form of the integral, and the general expression of the forces in the problems for which such integral exists. He examines, lastly, the general case of a point moving freely in space. The number of integrals common to several problems is here infinite. After giving a general form which comprehends them all, the author shows how to obtain as many particular forms as may be desired: it is, in fact, only necessary to resolve any problem relative to motion in a plane, and to effect a certain simple transformation on the integrals; one thus obtains a new equation which is the integral of an infinite number of different problems relating to the motion in space."

As an instance of the analytical forms on which these remarkable results depend, I quote the following, which is one of the most simple:—"If an integral of the equations of motion of a point in a plane belongs to two different problems, it is of the form

$$a=\mathrm{F}(\phi', x, y, t),$$

where ϕ' is the derivative with respect to t, of a function of x, y, which equated to zero gives the equation of a system of right lines."

56. Bertrand's memoir of 1851, 'On the Integration of the Differential Equations of Dynamics.'—The author refers to Jacobi's note of 1840, in relation to Poisson's theorem; and after remarking that there are very few problems of which two integrals are not known, and which therefore might not be solved by the method if it never failed; he observes that unfortunately there are (as was known) cases of exception, and that, as his me-

moir shows, these cases are far more numerous than those to which the method applies; thus for example the equation of *vis viva*, combined with any other integral whatever, leads to an illusory result. The theorem of Poisson may lead to an illusory result in two ways; either the resulting integral may be an identity $0=0$, or it may be an integral contained in the integrals already known, and which consequently does not help the solution. It appears by the memoir that the two cases are substantially the same, and that it is sufficient to study the case in which the two integrals lead to the identity $0=0$. Suppose that one integral is given, the author shows that there always exist integrals which, combined with the given integral, lead to an illusory result, and he shows how the integrals which, combined with the given integral, lead to such illusory result, are to be obtained. For instance, in the case of a body moving round a fixed centre, there are here two known integrals; first, the equation of *vis viva* (but this, as already remarked, combined with any other integral whatever, leads to an illusory result); secondly, the equation of areas.

The question arises, what are the integrals which, combined with the equation of areas, lead to an illusory result? The integrals in question are, in fact, the other two integrals of the problem; so that the inquiry into the integrals which give an illusory result, leads here to the completion of the solution. The like happens in two other cases which are considered, viz. 1. the problem of two fixed centres, and the problem of motion *in plano* when the forces are homogeneous functions of the coordinates of the degree. 2. Indeed the case is the same for all problems whatever, where the coordinates of the points of the system can be expressed by means of two independent variables.

The next problem considered is that where two bodies attract each other, and are attracted to a fixed centre. Suppose, first, the motion is *in plano*, then as in the former case *all* the integrals will be found by seeking for the integrals which, combined with the equation of areas, give an illusory result. When the motion is in space, the principle of areas furnishes three integrals (the equation of *vis viva* is contained in these three equations); the integrals which, combined with the integrals in question, give illusory results, are eight in number, and, to complete the solution, there must be added to these one other integral, which alone does not put the method in default. The problem of three bodies is then shown to be reducible to the last-mentioned problem; and the same consequences therefore hold good with respect to the problem of three bodies, viz., there are eight integrals which, combined with the integrals furnished by the principle of areas, give illusory results. To complete the solution it would be necessary to add to these a ninth integral, which alone would not put the method into default.

57. The author remarks that it appears by the preceding enumeration that the method of integration, based on the theorem of Poisson, is far from having all the importance attributed to it by Jacobi. The cases of exception are numerous; they constitute, in certain cases, the complete solutions of the problems, and embrace in other cases eleven integrals out of twelve. But it would be a misapprehension of his meaning to suppose that, according to him, the cases in which Poisson's theorem is usefully applicable ought to be considered as exceptions. The expression would not be correct even for the problems, which are completely resolved in seeking for the integrals which put the method into default; there exists for these problems, it is true, a system of integrals which give illusory results; but these integrals, combined in a suitable manner, might furnish others to which the theorem could be usefully applied.

The author remarks, that, in seeking the cases of exception to Poisson's theorem, there is obtained a new method of integration, which may lead to useful results; and, after referring to Jacobi's memoir on the elimination of the nodes in the problem of three bodies, he remarks that, by his own new method, the problem is reduced to the integration of six equations, all of them of the first order; so that he effectuates one more integration than had been done by Jacobi; and he refers to a future memoir (not, I believe, yet published) for the further development of his solution.

58. To give an idea of the analytical investigations, the equations of motion are considered under the Hamiltonian form

$$\frac{dq}{dt}=\frac{d\mathrm{H}}{dp},\ \frac{dp}{dt}=-\frac{d\mathrm{H}}{dq},$$

where H is any function whatever of $q, \ldots p, \ldots$ without t, and then a given integral being

$$\alpha=\phi(q, \ldots p, \ldots),$$

the question is shown to resolve itself into the determination of an integral $\beta=\psi(q, \ldots p, \ldots)$, such that identically $(\alpha, \beta)=0$ or else $(\alpha, \beta)=1$, where (α, β) represents, as before, Poisson's symbol, viz.

$$(\alpha, \beta)=\frac{\partial(\alpha, \beta)}{\partial(q, p)}+\ldots$$

if for shortness

$$\frac{\partial(\alpha, \beta)}{\partial(q, p)}=\frac{\partial\alpha}{dq}\frac{d\beta}{dp}-\frac{d\alpha}{dp}\frac{d\beta}{dq}.$$

The partial differential equations $(\alpha, \beta)=0$ or $(\alpha, \beta)=1$, satisfied by certain integrals β, are in certain cases, as Bertrand remarks, a precious method of integration leading to the classification of the integrals of a problem, so as to facilitate their ulterior determination: it is in fact by means of them that the several results before referred to are obtained in the memoir.

59. Bertrand's note of 1852 in the 'Comptes Rendus.'—This contains the demonstration of a theorem analogous to Poisson's theorem $(\alpha, \beta)=$const., but the function on the left-hand side is a function involving four of the arbitary constants and binary combinations of pairs of corresponding variables, instead of two arbitrary constants and the series of pairs of corresponding variables.

60. Bertrand's notes, vi. and vii., to the third edition of the 'Mécanique Analytique,' 1853, contain a concise and elegant exposition of various theorems which have been considered in the present report. The latter of the two notes relates to the above-mentioned theorem of Poisson, and places the theorem in a very clear light, in fact, establishing its connexion with the theory of canonical integrals. Bertrand in fact shows, that, given any integral α of the differential equations (in the last-mentioned form, the whole number of equations being $2k$), then the solution may be completed by joining to the integral α a system of integrals $\beta_1, \beta_2 \ldots \beta_{2k-1}$, which, combined with the integral α, give to Poisson's equation an identical form, viz. which are such that

$$(\alpha, \beta_1,)=1 \cdot (\alpha, \beta_2)=0, \ldots (\alpha, \beta_{2k-1})=0.$$

This, he remarks, shows, that, given any integral α, the solution of the problem *may* be completed by integrals $\beta_1, \beta_2 \ldots \beta_{2k-1}$, which, combined with α, give all of them an identical form to the theorem of Poisson. But it is not to be supposed that all the integrals of the problem are in the same case. In fact, the most general integral is $\eta=\varpi(\alpha, \beta_1, \beta_2 \ldots \beta_{2k-1})$, and it is at once

seen that $(\alpha, \eta)=(\alpha, \beta_1)\dfrac{d\eta}{d\beta_1}=\dfrac{d\eta}{d\beta_1}$, consequently the expression (α, η) will not be identically constant unless $\dfrac{d\eta}{d\beta_1}$ is so: but the integrals, in number infinite, which result from the combination of α, with $\beta_2, \beta_3 \dots \beta_{2k-1}$ combined with the integral α, give identical results. Only the integrals which contain β_1 lead to results which are not identical. The integrals α and β_1, connected together in the above special manner, are termed by the author *conjugate integrals*.

61. Brioschi's two notes of 1853.—The memoir 'Sulla Variazione,' &c. contains reflections and developments in relation to Bertrand's method of integration and to canonical systems of integrals, but I do not perceive that any new results are obtained.

The note, 'Intorno ad un Teorema di Meccanica,' contains a demonstration of the theorem in Bertrand's note of 1852 in the 'Comptes Rendus,' and an extension of the theorem to the case of a combination of any even number of the arbitrary constants; the value of the symbol is shown by the theory of determinants to be a function of the Poissonian coefficients (α, β), and as these are constants, the value of the symbol considered is also constant.

62. Liouville's note of the 29th of June, 1853*, contains the enunciation of a theorem which completes the investigations contained in Poisson's memoir of 1837. The equations considered are the Hamiltonian equations in their most general form, viz., H is any function whatever of t and the other variables: it is assumed that half of the integrals are known, and that the given integrals are such that for any two of them α, β, Poisson's coefficient (α, β) is equal to zero; this being so, the expression $pdq+\dots-\mathrm{H}dt$, where, by means of the known integrals, the variables $p, \dots$ are expressed in terms of $q, \dots t$, is a complete differential in respect to $q, \dots t$, viz. it will be the differential of Sir W. R. Hamilton's principal function V, which is thus determined by means of the known integrals, and the remaining integrals are then given at once by the general theory.

63. Professor Donkin's memoir of 1854 and 1855, Part I. (sections 1, 2 3, articles 1 to 48).—The author refers to the researches of Lagrange, Poisson, Sir W. R. Hamilton, and Jacobi, and he remarks that his own investigations do not pretend to make any important step in advance. The investigations contained in section 1, articles 1 to 14, establish by an inverse process (that is, one setting out from the integral equations) the chief conclusions of the theories of Sir W. R. Hamilton and Jacobi, and in particular those relating to the canonical system of elements as given by Jacobi's theory. The theorem (3), article 1, which is a very general property of functional determinants, is referred to as probably new. The most important results of this portion of the memoir are recapitulated in section 4, in the form of seven theorems there given without demonstration; some of these will be presently again referred to. Articles 17 and 18 contain, I believe, the only demonstration which has been given of the equivalence of the generalised Lagrangian and Hamiltonian systems. The transformation is as follows: the generalised Lagrangian system is

* The date is that of the communication of the note to the Bureau of Longitudes, but the note is only published in Liouville's Journal in the May Number for 1855, which is subsequent to the date of the second part of Professor Donkin's memoir in the 'Philosophical Transactions,' which contains the theorem in the question. I have not had the opportunity of seeing a thesis by M. Adrien Lafon, Paris, 1854, where Liouville's theorem is quoted and demonstrated.

$$\frac{d}{dt}\frac{dZ}{dq'}=\frac{dZ}{dq},$$
$$\vdots$$

where Z is any function of t and of $q,\ldots q',\ldots$ And writing $\frac{dZ}{dq'}=p,\ldots,$ then if $H=-Z+q'p+\ldots,$ where, on the right-hand side, $q',\ldots$ are expressed in terms of $t, q,\ldots p,\ldots,$ so that H is a function of $t, q,\ldots p,\ldots;$ then the theorems in the preceding articles show that

$$\frac{dq}{dt}=\frac{dH}{dp},\ \frac{dp}{dt}=-\frac{dH}{dq},$$
$$\vdots \qquad \vdots$$

which is the generalised Hamiltonian system.

In section 2, articles 21 and 22, there is an elegant demonstration, by means of the Hamiltonian equations, of the theorem in relation to Poisson's coefficients (a, b), viz., that these coefficients are functions of the elements only. And there are contained various developments as to the consequences of this theorem; and as to systems of canonical, or, as the author calls them, *normal* elements. The latter part of the section and section 3, relate principally to the special problems of the motion of a body under the action of a central force, and of the motion of rotation of a solid body.

64. Part II. (sections 4, 5, 6 and 7, articles 49–93, appendices).—Section 4 contains the seven theorems before referred to. Although not given as new theorems, yet, to a considerable extent, and in form and point of view, they are new theorems.

Theorem 1 is a theorem standing apart from the others, and which is used in the demonstration of the transformation from the Lagrangian to the Hamiltonian system. It is as follows: viz., if X be a function of the n variables $x,\ldots,$ and if $y,\ldots$ be n other variables connected with these by the n equations

$$\frac{dX}{dx}=y,\ldots$$

then will the values of $x,\ldots,$ expressed by means of these equations in terms of $y,\ldots,$ be of the form

$$x=\frac{dY}{dy},\ldots$$

and if p be any other quantity explicitly contained in X, then also

$$\frac{dX}{dp}+\frac{dY}{dp}=0,$$

the differentiation with respect to p being in each case performed only so far as p appears explicitly in the function.

The value of Y is given by the equation

$$Y=-X+xy+\ldots$$

where, on the right-hand side, $x,\ldots$ are expressed in terms of $y,\ldots$

Theorems 2, 3 and 4, and a supplemental theorem in article 50, relate to the deduction of the generalised Hamiltonian system of differential equations from the integral equations assumed to be known. In fact (writing $V, q,\ldots p,\ldots b,\ldots a,\ldots,$ instead of the author's $X, x_1\ldots x_n, y_1\ldots y_n, a_1\ldots a_n, b_1\ldots b_n$), it is assumed that V is a given function of t, of the n va-

riables $q,\ldots$, and of the n constants $b,\ldots$, and that the n variables $p,\ldots$, and the n constants $a,\ldots$, are determined by the conditions

$$\frac{dV}{dq}=p,\ldots \quad (1)$$

$$\frac{dV}{db}=a,\ldots \quad (2)$$

so that in fact by virtue of these $2n$ equations the $2n$ variables X, $q,\ldots$ $p,\ldots$ may be considered as functions of t, and the $2n$ constants $b,\ldots a,\ldots$ (hypothesis 1), or conversely, the $2n$ constants $b,\ldots a,\ldots$, may be considered as functions of t and of the $2n$ variables $q,\ldots p,\ldots$ (hypothesis 2).

Theorem 2 is as follows: viz., if from the $2n$ equations (1, 2) and their total differential coefficients with respect to t, the $2n$ constants be eliminated, there will result the following $2n$ simultaneous differential equations of the first order, viz.:—

$$\frac{dq}{dt}=\frac{dH}{dp}\ldots$$

$$\frac{dp}{dt}=-\frac{dH}{dq}\ldots$$

where H is a function of $q,\ldots p,\ldots$ (which will in general also contain t explicitly), and is given by the equation

$$H=-\frac{dV}{dt},$$

where, on the right-hand side, the differential coefficient $\frac{dV}{dt}$ is taken with respect to t, in so far as t appears explicitly in the original expression for V in terms of $q,\ldots b,\ldots$ and t, and after the differentiation, $b,\ldots$, are to be expressed in terms of the variables and t, by means of the equations (1).

Theorem 3 is, that there exists the following relations, viz.:—

$$\frac{dq}{db}=-\frac{da}{dp}, \frac{dq}{da}=\frac{db}{dp}\ldots$$

$$\frac{dp}{db}=\frac{da}{dq}, \frac{dp}{da}=-\frac{db}{dq},$$

where (p, q) are *any* corresponding pair out of the systems $p,\ldots$ and $q,\ldots$, and (b, a) are any corresponding pair out of the systems $b,\ldots$ and $a,\ldots$, so that the total number of equations is $4n^2$: in each of the equations the left-hand side refers to hypothesis 1, and the right-hand side to hypothesis 2.

To these theorems should be added the supplemental theorem contained in article 50, viz., that there subsists also the system of equations

$$\frac{db}{dt}=\frac{dH}{da}\ldots$$

$$\frac{da}{dt}=-\frac{dH}{db}\ldots$$

where the left-hand sides refer to hypothesis 2, while the right-hand sides refer to hypothesis 1, as before $H=-\frac{dV}{dt}$, but here H is differentially expressed, being what the H of theorem 3 becomes when the variables are expressed according to hypothesis 1.

In theorem 4 the author's symbol (p, q) has a signification such as Poisson's (a, b), and if we write as before

$$(a,b)=\frac{\partial(a, b)}{\partial(p, q)}+\dots$$

where

$$\frac{\partial(a, b)}{\partial(p, q)}=\frac{da}{dp}\frac{db}{dq}-\frac{db}{dp}\frac{da}{dq}$$

(this refers of course to hypothesis 2), the theorem is, that the following equations subsist identically, viz., b, a being corresponding constants out of the two series $b, \dots$ and $a, \dots$, then

$$(b, a)=-(a, b)=1,$$

but that for any other pairs b, a, or for any pairs whatever b, b or a, a, the corresponding symbol $=0$: in fact, that the constants $b, \dots$ and $a, \dots$ form a canonical system of elements.

Theorem 5 is a theorem including theorem 4, and relating to any two functions u, v either of the two $2n$ constants or else of the $2n$ variables, and which may besides contain t explicitly; it establishes, in fact, a relation between Poisson's coefficient (u, v) and the corresponding coefficient of Lagrange.

Theorem 6 is as follows: viz., if $q, \dots p, \dots$ are any $2n$ variables concerning which no supposition is made, except that they are connected by the n equations

$$b=\phi(q, \dots p, \dots),$$

which equations are only subject to the condition of being sufficient for the determination of $p, \dots$ in terms of $q, \dots$ and $a, \dots$, and they may contain explicitly any other quantities, for example, a variable t. Then, in order that the $\frac{1}{2}n(n-1)$ equations

$$\frac{dp_i}{dq_j}=\frac{dp_j}{dq_i}$$

may subsist identically, it is only necessary that each of the $\frac{1}{2}n(n-1)$ equations $(b_i, b_j)=0$ may be satisfied identically.

Theorem 7 is, in fact, the theorem previously established in its general form in Liouville's note of the 29th of June, 1853, viz., if, of the system of $2n$ differential equations

$$\frac{dq}{dt}=\frac{dH}{dp}, \frac{dp}{dt}=-\frac{dH}{dq},$$

there be given n integrals involving the n arbitrary constants $b, \dots$, so that each of these constants can be expressed as a function of the variables $q, \dots p, \dots$ (with or without t); then, *if the* $\frac{1}{2}n(n-1)$ *conditions* $(b_i, b_j)=0$ *subsist identically, the remaining* n *integrals can be found as follows*:—By means of the n integrals, let the n variables $p, \dots$ be expressed in terms of $x, \dots b, \dots$ and t, and let H stand for what H, as originally given, becomes when $q, \dots$ are thus expressed. Then the values of $p, \dots$ and $-H$ are the differential coefficients of one and the same function of $p, \dots$ and t; call this function V, then, since its differential coefficients are all given (by the equations $\frac{dV}{dq}=p, \dots \frac{dV}{dt}=-H$), V may be found by integration; and it is therefore to be considered as a given function of $p, \dots$ and t and of the constants $b, \dots$. The remaining n integrals are given by the n equations

$$\frac{dV}{db}=a, \ldots$$

where the n quantities $a, \ldots$ are new arbitrary constants.

65. Section 5 of the memoir relates to the theory of the variation of the elements considered in relation to the following very general problem: viz., $Q, \ldots$ $P, \ldots$ being any functions whatever of the $2n$ variables $q, \ldots$ $p, \ldots$ and t; it is required to express the integrals of the system $2n$ differential equations

$$\frac{dq}{dt}=P, \ \frac{dp}{dt}=Q$$
$$\vdots \qquad \vdots$$

in the same form as the integrals (supposed given) of the standard system

$$\frac{dq}{dt}=\frac{dH}{dp}, \ \frac{dp}{dt}=-\frac{dH}{dq}$$
$$\vdots \qquad \vdots$$

by substituting functions of t for the constant elements of the latter system. And section 6 contains some very general researches on the general problem of the transformation of variables, a problem of which, as the author remarks, the method of the variation of elements is a particular, and not the only useful case. In particular, the author considers what he terms a normal transformation of variables, and he obtains the theorem 8, which includes as a particular case the second of the two theorems in Jacobi's note of 1837, in the 'Comptes Rendus.' This theorem is as follows: viz., if the original variables $q, \ldots p, \ldots$ are given by the $2n$ equations

$$\frac{dq}{dt}=\frac{dH}{dp}, \ \frac{dp}{dt}=-\frac{dH}{dq};$$
$$\vdots$$

and if the new variables $\eta, \ldots \varpi, \ldots$ are connected with the original variables by the equations

$$\frac{dK}{dp}=q, \ \frac{dK}{d\eta}=\varpi;$$
$$\vdots$$

where K is any function of $\eta, \ldots p, \ldots$ which may also contain t explicitly, then will the transformed equations be

$$\frac{d\eta}{dt}=\frac{d\Phi}{d\varpi}, \ \frac{d\varpi}{dt}=-\frac{d\Phi}{d\eta};$$

in which Φ is defined by the equation

$$\Phi=H-\frac{dK}{dt},$$

and is to be expressed in terms of the new variables, the substitution of the new variables in $\frac{dK}{dt}$ being made after the differentiation. In particular, if K does not contain t explicitly, then $\frac{dK}{dt}=0$ and $\Phi=H$, so that, in this case, the transformation is effected merely by expressing H in terms of the new variables. There is also an important theorem relating to the *transformation of coordinates.* To explain this, it is necessary to go back to the generalised Lagrangian form

$$\frac{d}{dt}\frac{dZ}{dq'}=\frac{dZ}{dq};$$

where the variables $q, \ldots$ correspond to the coordinates of a dynamical problem; if the new variables $\eta, \ldots$ are any given functions whatever of the original variables $q, \ldots$ and of t, this is what may be termed a transformation of coordinates. But the proposed system can be expressed, as shown in the former part of the memoir, in the generalised Hamiltonian form with the variables $q, \ldots$ and the derived variables $p, \ldots$ (the values of which are given by $\frac{dZ}{dq}=p, \ldots$): the problem is to transform the last-mentioned system by introducing, instead of the original coordinates $q, \ldots$, the new coordinates $\eta, \ldots$, and instead of the derived variables $p, \ldots$. the new derived variables $\varpi, \ldots$ defined by the analogous equations $\frac{dZ}{d\eta}=\varpi, \ldots$, in which Z is supposed to be expressed as a function of $\eta, \ldots$ and t. The method of transformation is given by the theorem 9, which states that the transformation is a normal transformation, and that the modulus of transformation (that is, the function corresponding to K in theorem 8) is

$$K=qp+\ldots$$

where $q, \ldots$ are to be expressed in terms of $\eta, \ldots$. The latter part of the same section contains researches relating to the case where the proposed equations are symbolically, but not actually, in the Hamiltonian form, viz., where the function H is considered as containing functions of $q, \ldots$ $p, \ldots$ which are exempt from differentiation in forming the differential equations (the author calls this a pseudo-canonical system), and where, in like manner, the transformation of variables is a pseudo-normal transformation; the theorems 10 and 11 relate to this question, which is treated still more generally in Appendix C. The general methods are illustrated by applications to the problem of three bodies and the problem of rotation; the former problem is specially discussed in section 7; but the results obtained (and which, as the author remarks, affords an example of the so-called 'elimination of the nodes') do not come within the plan of the present report.

66. Bour's memoir of 1855, 'On the Integration of the Differential Equations of Analytical Mechanics.'—It has been already seen that the knowledge of half of the entire system of the integrals of the differential equations (these known integrals satisfying certain conditions) leads by quadratures only to the knowledge of the remaining integrals; the researches contained in this most interesting and valuable memoir show that this theorem is, in fact, only the last of a series of theorems, here first established, relating to the successive reduction which results from the knowledge of each new integral. Speaking in general terms, it may be stated that the author operates on the linear partial differential equation of the first order, which is satisfied by the integrals of the differential equations; and that he effectuates upon this equation a reduction of two unities in the number of variables for every suitable new integral which is obtained*. The author shows also that an equal or greater reduction may

* I have borrowed this and the next sentence from Liouville's report. It would, I think, be more accurate to say, for every suitable new integral after the first one; in the case considered in the memoir, the condition of *vis viva* is satisfied, and there is always one integral, the equation of *vis viva*, which is known; but this alone, and in the general case the first known integral, will not cause a reduction of two unities.

sometimes be obtained by means of integrals which appear at first foreign to his method. Before going further, it may be convenient to remark that the author restricts himself to the case in which H is independent of the time, and where, consequently, the condition of *vis viva* is satisfied; it was, however, remarked by Liouville that the analysis, slightly modified, applies to the most general case where H is any function of t and the variables, and it is possible that when the entire memoir is published (it is given in 'Liouville's Journal' as an extract), the theory will be exhibited under this more general form.

67. To give an idea of the analytical results, the equations are considered under the form

$$\frac{dp_i}{dt}=\frac{d\mathrm{H}}{dq_i}, \frac{dq_i}{dt}=-\frac{d\mathrm{H}}{dq_i} \ (i=1 \text{ to } i=n)$$

(where, as already remarked, H is independent of t). The integrals admit, therefore, of representation in the canonical form $\alpha, \beta, \alpha_1, \alpha_2, \ldots \alpha_{2n-2}$ where $\alpha(=\mathrm{H})$ is the equation of *vis viva* $\beta(=\mathrm{G}-t)$ is the integral conjugate to this, and the only integral involving the time, and the remaining integrals α_1 and α_2, α_3 and $\alpha_4 \ldots \alpha_{2n-3}$ and α_{2n-2} are conjugate pairs, we have (α_1, α) $(=(\alpha_1, \mathrm{H}))=0$, (α_1, β) $(=(\alpha_1, \mathrm{G}))=0$, $(\alpha_1, \alpha_2)=1$, (α_1, α_3) $=0, \ldots (\alpha_1, \alpha_{2n-2})=0$.

The integrals $\alpha_1, \alpha_2 \ldots \alpha_{2n-2}$ verify the linear partial differential equation

$$\Sigma_{i=1}^{i=n}\left(\frac{d\mathrm{H}}{dq_i}\frac{d\zeta}{dp_i}-\frac{d\mathrm{H}}{dp_i}\frac{d\zeta}{dq_i}\right)=0 \text{ or } (\mathrm{H}, \zeta)=0 \ (1),$$

which is also satisfied by $\zeta=\mathrm{H}$, and of which the general solution is $\zeta=\phi(\mathrm{H}, \alpha_1, \alpha_2 \ldots \alpha_{2n-2})$, while, on the contrary, the first member of the equation (1), becomes unity for $\zeta=\mathrm{G}$, in other words $(\mathrm{H}, \mathrm{G})=1$. The equation (1) replaces the original differential equations; it is to the equation (1) that the theorems of Poisson and Bertrand may be supposed to be applied, and it is this equation (1) which is studied in the memoir, where it is shown how the order may be diminished when one or more integrals are known.

In the first place, the integral $\alpha=\mathrm{H}$ which is known, may be made use of to eliminate one of the variables, suppose p_n; the result is found to be

$$\Sigma_{i=1}^{l=n-1}\left(\frac{dp_n}{dq_i}\frac{d\zeta}{dp_i}-\frac{dp_n}{dp_i}\frac{d\zeta}{dq_i}\right)+\frac{d\zeta}{dq_n}=0 \ (2),$$

which has the same integrals as the equation (1), except the integral of *vis viva* $\zeta=\mathrm{H}$; it is this equation (2) which would have to be integrated if only the integral α were known.

Suppose now there is known a new integral α_1; this gives rise to the partial differential equation

$$\Sigma_{i=1}^{l=n}\left(\frac{d\alpha_1}{dq_i}\frac{d\zeta}{dp_i}-\frac{d\alpha_1}{dp_i}\frac{d\zeta}{dq_i}\right)=0 \text{ or } (\alpha_1, \zeta)=0 \ (4),$$

which is satisfied by $\zeta=\mathrm{H}, \mathrm{G}, \alpha_1, \alpha_3, \alpha_4 \ldots \alpha_{2n-2}$, but not by α_2, which gives $(\alpha_1, \alpha_2)=0$. The equation (4) is satisfied $\zeta=\mathrm{H}$, and it may be therefore transformed in the same manner as the equation (1) was, viz. p_n may be expressed in terms of the other variables and of α. The author remarks that it will happen, what causes the success of the method, that this operation, the object of which is to get rid of the solution $\zeta=\mathrm{H}$, conducts to two different equations, according as $\zeta=\mathrm{G}$ or $\zeta=$ any other integral of the

equation (4); so that in the second form of the transformed equation the unknown integral $\zeta=G$ is also eliminated. This second form is found to be

$$\Sigma_{i=1}^{l=n-1}\left(\frac{d\alpha_1}{dq_i}\frac{d\zeta}{dp_i}-\frac{d\alpha_1}{dp_i}\frac{d\zeta}{dq_i}\right)=0 \text{ or } (\alpha_1,\zeta)=0 \quad (5),$$

which is precisely similar to the equation (1) (only the number of variables is diminished by two unities), and is possessed of the same properties. Its integrals are $\alpha_1, \alpha_3, \alpha_4 \ldots \alpha_{2n-2}$, which are all of them integrals of the problem, and give $(\alpha_1, \alpha_i)=0$. And the theorems of Poisson and Bertrand apply equally to this equation; the only difference is, that the number of terms in the expressions (α, β) is less by two unities. A new integral (α_3) leads in like manner to an equation (8) similar to (5), but with the number of variables further diminished by two unities, and so on, until the half series of integrals $\alpha, \alpha_1, \alpha_3 \ldots \alpha_{2n-3}$ are known; the conjugate integrals $\beta, \alpha_2, \alpha_4 \ldots \alpha_{2n-2}$ are then obtained by quadratures only, in the method explained in the memoir, and which is in fact identical with that given by the theorem of Liouville and Donkin. The memoir contains other results, which have been already alluded to in a general manner; some of these are made use of by the author in his 'Mémoire sur les problêmes des trois corps,' Journal Polyt., t. xxi. pp. 35–58 (1856).

68. Liouville's note of July, 1855, on the occasion of Bour's memoir, mentions that the author of the memoir had recognized that, according to the remark made to him, his formulæ subsist with even increased elegance when H is considered as a function of t and the other variables. But (it is remarked) the general case can be always reduced to the particular one considered in the memoir, provided that the number of equations is augmented by two unities by the introduction of the new variables τ and u, the former of them, τ, equal to $t+$constant, so that

$$\frac{dt}{d\tau}=1$$

the latter of them, u, defined by the equation

$$\frac{du}{d\tau}=-\frac{dH}{dt}.$$

Suppose in fact that

$$V=H+u,$$

then, since τ and u do not enter into H, which is a function only of t and the variables $q, \ldots p, \ldots$, we have

$$\frac{dV}{du}=1=\frac{dt}{d\tau};$$

and, moreover, the differential coefficients with respect to $t, q, \ldots p, \ldots$ of the functions H and V are equal. The system may be written

$$\frac{dt}{d\tau}=\frac{dV}{du}, \quad \frac{du}{d\tau}=-\frac{dV}{dt}$$

$$\frac{dp}{d\tau}=\frac{dV}{dq}, \quad \frac{dq}{d\tau}=-\frac{dV}{dp}$$

$$\vdots \qquad\qquad \vdots$$

which is a system containing two more variables, but in which V is independent of the variable τ, which stands in the place of t. The transforma-

tion is an elegant and valuable one, but it is not in anywise to be inferred that there is any advantage in considering the particular case (which is thus shown to be capable of including the general one), rather than the general one itself: such inference does not seem to be intended, and would, I think, be a wrong one.

69. Brioschi's note of 1855 contains an elegant demonstration (founded on the theory of skew determinants) of a property which appears to be a new one, of the canonical integrals of a dynamical problem, viz. if q,p stand for a corresponding pair of the variables $q,\ldots p,\ldots$ then

$$\Sigma\frac{\partial(\alpha,\beta)}{\partial(q,p)}=1$$

where the summation refers to all the different pairs of conjugate integrals α,β of the canonical system, the pair q,p in the denominator being the same in each term; but if the variables in the denominator are a non-corresponding pair out of the two series $q,\ldots$ and $p,\ldots$, or else a pair out of one series only (that is, both q's or both p's), then the expression on the left-hand side is equal to zero. This is in fact a sort of reciprocal theorem to the theorem which defines the canonical system of integrals. There are two or three memoirs of Brioschi in Crelle's Journal connected with this note and the note of 1853; but as they relate professedly to skew determinants and not to the equations of dynamics, it is not necessary here to refer to them more particularly.

70. Bertrand's memoir of 1857 forms a sequel to the memoir of 1851, on the integrals common to several problems of mechanics. The author calls to mind that he has shown in the first memoir, that, given an integral of a mechanical problem, and assuming only that the forces are functions of the coordinates, it is possible to determine the problem and find the forces which act upon each point; and (he proceeds) it is important to remark, that the solution leads often to contradictory results,—that, in fact, an equation assumed at hazard is not in general an integral of any problem whatever of the class under consideration: and he thereupon proposes to himself in the present memoir to develope some of the consequences of this remark, and to seek among the most simple forms, the equations which can present themselves as integrals, and the problems to which such integrals belong. The various special results obtained in the memoir are interesting and valuable.

71. In what precedes I have traced as well as I have been able the series of investigations of geometers in relation to the subject of analytical dynamics. The various theorems obtained have been in general stated with sufficient fulness to render them intelligible to mathematicians; the attempt to state them in a uniform notation and systematic order would be out of the province of the present report. The leading steps are,—first, the establishment of the Lagrangian form of the equations of motion; secondly, Lagrange's theory of the variation of the arbitrary constants, a theory perfectly complete in itself; and it would not have been easy to see *à priori* that it would be less fruitful in results than the theory of Poisson; thirdly, Poisson's theory of the variation of the arbitrary constants, and the method of integration thereby afforded; fourthly, Sir W. R. Hamilton's representation of the integral equations by means of a single characteristic function determinable *à posteriori* by means of the integral equations assumed to be known, or by the condition of its simultaneous satisfaction of two partial differential equations; fifthly, Sir W. R. Hamilton's form of the equations of motion; sixthly, Jacobi's reduction of the integration of the differential equations to the problem of finding a complete integral of a single partial differential

equation, and the general theory of the connexion of the integration of a system of ordinary differential equations, and of a partial differential equation of the first order, a theory, however, of which Jacobi can only be considered as the second founder; seventhly, the notion (arising from the researches of Lagrange and Poisson) and ulterior development of the theory of a system of canonical integrals.

I remark in conclusion, that the differential equations of dynamics (including in the expression, as I have done throughout the report, the generalized Lagrangian and Hamiltonian forms) are only one of the classes of differential equations which have occupied the attention of geometers. The greater part of what has been done with respect to the general theory of a system of differential equations is due to Jacobi, and he has also considered in particular, besides the differential equations of dynamics, the Pfaffian system of differential equations (including therein the system of differential equations which arise from any partial differential equation of the first order), and the so-called isoperimetric system of differential equations, that is, the system arising from any problem in the calculus of variations. In a systematic treatise it would be proper to commence with the general theory of a system of differential equations, and as a branch of this general theory, to consider the generalized Hamiltonian system, and in relation thereto to develope the various theorems which have a dynamical application. It would be shown that the generalized Lagrangian form could be transformed into the Hamiltonian form, but the first-mentioned form would, I think, properly be treated as a particular case of the isoperimetric system of differential equations.

List of Memoirs and Works above referred to.

Lagrange. Mécanique Analytique. 1st edition. 1788.

Laplace. Mécanique Céleste, t. i. 1799.

Poisson. Sur les inégalités séculaires des moyens mouvemens des planètes. Read to the Institute 20th June, 1808.—Journ. Polyt. t. viii. pp. 1–56. 1808.

Laplace. Mémoire . . . . . Read to the Bureau of Longitudes 17th Aug. 1808.—Forms an Appendix to the 3rd volume of the Mécanique Céleste. 1808.

Lagrange. Mémoire sur la théorie des variations des éléments des planètes et en particulier des variations des grands axes de leurs orbites. Read to the Bureau of Longitudes the 17th Aug. and to the Institute the 22nd Aug., 1808.—Mém. de l'Instit., 1808, pp. 1–72. 1808.

Lagrange. Mémoire sur la théorie générale de la variation des constantes arbitraires dans tous les problêmes de la Mécanique. Read to the Institute 13th March, 1809.—Mém. de l'Instit., 1808, pp. 257–302 (includes an undated addition), and there is a Supplement also without date, pp. 363, 364. 1809.

Poisson. Mémoire sur la variation des constantes arbitraires dans les questions de Mécanique. Read to the Institute 16th Oct., 1809.—Journal Polyt., t. viii. pp. 266–344. 1809.

Lagrange. Seconde mémoire sur la variation des constantes arbitraires dans les problêmes de Mécanique, dans lequel on simplifie l'application des formules générales à ces problêmes. Read to the Institute 19th Feb., 1810.—Mém. de l'Instit., 1809, pp. 343–352. 1810.

Lagrange. Mécanique Analytique. 2nd edition, t. i., 1811; t. ii., 1813. 1811.

Poisson. Mémoire sur la variation des constantes arbitraires dans les questions de Mécanique. Read to the Academy, 2nd Sept., 1816.—Bulletins de la Soc. Philom., 1816, p. 109; and also, Mém. de l'Instit., t. i., pp. 1–70. 1816.

Hamilton, Sir W. R. On a general method in Dynamics, by which the study of all free systems of attracting or repelling points is reduced to the search and differentiation of one central relation or characteristic function.—Phil. Trans. for 1834, pp. 247–308. 1834.

Hamilton, Sir W. R. Second Essay on a general method in Dynamics.—Phil. Trans. for 1835, pp. 95–144. 1835.

Poisson. Remarques sur l'intégration des équations différentielles de la dynamique.—Liouville, t. ii. pp. 317–337. 1837.

Jacobi. Lettre à l'Académie.—Comptes Rendus, t. iii. pp. 59–61. 1836.

Jacobi. Zur Theorie der Variations-Rechnung und der Differential-Gleichungen. Extract from a letter of the 29th Nov. 1836, to Professor Encke, secretary of the mathematical class of the Academy of Berlin.—Crelle, t. xvii. pp. 68–82. 1836.

Jacobi. Ueber die Reduction der Integration der partiellen Differentialgleichungen erster Ordnung zwischen irgend einer Zahl Variabeln auf die Integration eines einzigen Systemes gewöhnlicher Differentialgleichungen.—Crelle, t. xxvii. pp. 97–162, and translated into French, Liouville, t. iii. pp. 60–96, and 161–201. 1837.

Jacobi. Note sur l'intégration des équations différentielles de la dynamique.—Comptes Rendus, t. v. pp. 61. 1837.

Jacobi. Neues Theorem der analytischen Mechanik.—Monatsbericht of the Academy of Berlin for 1838 (paper is dated 21st Nov., 1838); and Crelle, t. xxx. pp. 117–120. 1838.

Jacobi. Lettre adressée à M. le Président de l'Académie des Sciences à Paris.—Comptes Rendus, t. xi. p. 529; Liouville, t. v. pp. 350–351 (with an addition by Liouville, pp. 351–355). 1840.

Binet. Mémoire sur la variation des constantes arbitraires dans les formules générales de la dynamique et dans un système d'équations analogues plus étendues.—Journ. Polyt. t. xvii. pp. 1–94. 1841.

Jacobi. Sur un nouveau principe général de la Mécanique Analytique.—Comptes Rendus, t. xv. pp. 202–205. 1842.

Jacobi. De motu puncti singularis.—Crelle, t. xxiv. pp. 5–27. 1842.

Maurice. Mémoire sur la variation des constantes arbitraires comme l'ont établie dans sa généralité les mémoires de Lagrange et celui de Poisson. Read to the Academy the 3rd June, 1844.—Mém. de l'Institut, t. xix. pp. 553–638. 1844.

Jacobi. Theoria novi multiplicatoris systemati æquationum differentialium vulgarium applicandi.—Crelle, t. xxvii. pp. 199–268; and t. xxix. pp. 213–279, and 333–376. 1844.

Desboves. Démonstration de deux théorèmes de M. Jacobi, application au problême des perturbations planétaires. Thesis presented to the Faculty of Sciences the 3rd April, 1848.—Liouville, t. xiii. pp. 397–411. 1848.

Serret. Sur l'intégration des équations différentielles du mouvement d'un point matériel.—Comptes Rendus, t. xxvi. pp. 605–610. 1848.

Serret. Sur l'intégration des équations différentielles de la dynamique.—Comptes Rendus, t. xxvi. pp. 639–643. 1848.

Sturm. Note sur l'intégration des équations générales de la dynamique.—Comptes Rendus, t. xxvi. pp. 658–673. 1848.

Ostrogradsky. Sur les intégrales des équations générales de la dynamique.—Mélanges de l'Acad. de St. Pétersbourg, $\frac{6}{18}$th Oct., 1848.

Brassinne. Théorème relatif à une classe d'équations différentielles simultanées analogue à un théorème employé par Lagrange dans la théorie des perturbations.—Liouville, t. xvi. pp. 283–288. 1851.

Bertrand. Mémoire sur les intégrales communes à plusieurs problèmes de Mécanique. Presented to the Academy the 12th May, 1851.—Liouville, t. xvii. pp. 121–174. 1851.

Bertrand. Mémoire sur l'intégration des équations différentielles de la dynamique.—Liouville, t. xvii. pp. 393–436. 1852.

Bertrand. Sur un nouveau théorème de Mécanique Analytique.—Comptes Rendus, t. xxxv. pp. 698–699. 1852.

Bertrand's notes VI. and VII. to the third edition of the Mécanique Analytique, t. i. pp. 409–428, viz. note VI.—Sur les équations différentielles des problêmes de la Mécanique et la forme que l'on peut donner à leurs intégrales; and note VII.—Sur un théorème de Poisson. 1853.

Brioschi. Sulla variazione delle costanti arbitrarie nei problemi della Dinamica.—Tortolini, Annali, t. iv. pp. 298–311. 1853.

Brioschi. Intorno ad un teorema di Meccanica.—Tortolini, Annali, t. iv. pp. 395–400. 1853.

Liouville. Note sur l'intégration des équations différentielles de la dynamique, presentée au Bureau des Longitudes le 29 Juin, 1853.—Liouville, t. xx. pp. 137–138. 1853.

Donkin, Prof. On a Class of Differential Equations, including those which occur in Dynamical Problems. Part I.—Phil. Trans. 1854, pp. 71–113. Received Feb. 23rd, read Feb. 23rd, 1854. 1854.

Donkin, Prof. On a Class of Differential Equations, including those which occur in Dynamical Problems. Part II.—Phil. Trans, 1855, pp. 299–358. Received Feb. 17th, read March 22d, 1855. 1855.

Liouville. Rapport sur un mémoire de M. Bour concernant l'intégration des équations différentielles de la Mécanique Analytique.—Comptes Rendus, t. xl. p. 661, séance du 26th Mars, 1855; Liouville, t. xx. pp. 135–136. 1855.

Bour. Sur l'intégration des équations différentielles de la Mécanique Analytique (extrait d'un mémoire présenté à l'Académie le 5 Mars, 1855).—Liouville, t. xx. pp. 185–200. 1855.

Liouville. Note à l'occasion du mémoire précédent de M. Edmond Bour.—Liouville, t. xx. pp. 201–202. 1855.

Brioschi. Sopra una nuova proprietà degli integrali di un problema di dinamica.—Tortolini, t. vi. pp. 430–432. 1855.

Bertrand. Mémoire sur quelqu'une des formes les plus simples que puissent prendre les intégrales des équations différentielles du mouvement dun point matériel.—Liouville, t. ii. (2e série), pp. 113–140. 1857.

Sixteenth and final Report of a Committee, consisting of Professor Daubeny, Professor Henslow, *and* Professor Lindley, *appointed to continue their Experiments on the Growth and Vitality of Seeds.*

When the summary, given in the Report for 1850, pp. 162 to 168, was made up, many of the kinds of seeds set apart for the continuation of these experiments had not ceased to germinate, which rendered a continuation of periodical sowings necessary to arrive at a satisfactory result. Such sowings have consequently been continued down to the present time, and so few* are now found to possess their vegetative powers, that it is deemed necessary to consider the object attained, and thus close these investigations.

The Committee submit the annexed General Summary, which contains all the results arrived at that are worth recording in this place.

Single sowings of a great many other kinds of seeds, mostly old, have been made during the time these experiments have been carried on; but as in most cases the probable age at which they ceased to germinate could not be traced, they are not inserted in the summary, but will be found entered in the MS. Register submitted with this Report.

General Summary of the Experiments from 1841 to 1857 inclusive.

Name.	Sown in	Age.	No. germinated.	No. sown.	Name.	Sown in	Age.	No. germinated.	No. sown.
1. Gramineæ.					2. Palmaceæ.				
1. Zea Mays	1846	1	198	300	9. Phœnix dactylifera	1843	1	2	9
" "	1848	3	127	300	" "	1845	3	5	9
" "	1853	8	nil.	300	" "	1850	8	nil.	9
2. Phalaris canariensis	1842	1	194	300	3. Amaryllidaceæ.				
" "	1844	3	147	300	10. Alstrœmeria pelegrina	1843	1	19	60
" "	1849	8	19	300	" "	1845	3	5	60
" "	1854	13	nil.	300	" "	1850	8	nil.	60
3. Panicum miliaceum	1849	2	178	600	" aurantia	1845	1	12	300
" "	1857	10	nil.	600	" "	1847	3	nil.	300
4. Avena sativa	1842	1	180	200	4. Iridaceæ.				
" "	1844	3	237	300	11. Sisyrinchium bermudianum	1848	2	1	100
" "	1849	8	37	300	12. Gladiolus psittacinus	1843	1	42	300
" "	1854	13	nil.	300	" "	1845	3	17	300
5. " "	1844	3	210	300†	" "	1850	8	nil.	300
" "	1857	16	nil.	300	13. Iris sibirica	1843	1	?	150
6. Triticum æstivum	1842	1	180	300	" "	1845	3	14	150
" "	1844	3	163	300	" "	1850	8	nil.	150
" "	1849	8	nil.	300	14. " sp.	1846	1	14	75
" "	1844	3	115	150†	" "	1848	3	4	75
" "	1857	16	nil.	150	" "	1853	8	nil.	75
" "	1844	3	140	300‡	15. Tigridia pavonia	1844	1	32	300
" "	1857	16	nil.	300	" "	1846	3	36	300
7. Secale cereale	1846	1	456	600	" "	1851	8	nil.	300
" "	1848	3	4	600	5. Liliaceæ.				
" "	1853	8	nil.	600	16. Allium fragrans	1844	1	143	300
8. Hordeum vulgare	1842	1	255	300	" "	1846	3	102	300
" "	1844	3	167	300	" "	1851	8	4	300
" "	1849	8	nil.	300	" "	1857	14	nil.	300
" "	1844	3	236	300†	" "	1847	10	2	450
" "	1857	16	nil.	300	" "	1854	17	nil.	450

* *Ulex, Dolichos, Malva, Ipomœa.* † (In waxed cloth.) ‡ (In open jars.)

Name.	Sown in	Age.	No. germinated.	No. sown.
5. LILIACEÆ, *continued.*				
16. Allium senescens	1848	4	3	60
17. Camassia esculenta	1847	10	1	300
„ „	1854	17	nil.	300
18. Asphodelus luteus	1844	1	52	150
„ „	1846	3	32	150
„ „	1851	8	1	150
„ „	1857	14	nil.	150
19. Asparagus officinalis	1845	1	251	450
„ „	1847	3	97	450
„ „	1852	8	nil.	450
6. PINACEÆ.				
20. Pinus Pinea	1846	12	3	19
21. Juniperus communis	1843	1	28	300
„ „	1845	3	nil.	300
7. BETULACEÆ.				
22. Alnus glutinosa	1846	1	111	450
„ „	1853	8	4	450
„ „	1857	13	nil.	450
8. CANNABINACEÆ.				
23. Cannabis sativa	1842	1	45	150
„ „	1849	8	13	150
„ „	1854	13	nil.	150
9. MORACEÆ.				
24. Morus nigra	1843	1	82	300
„ „	1845	3	59	300
„ „	1850	8	nil.	300
10. EUPHORBIACEÆ.				
25. Euphorbia Lathyris	1844	1	20	150
„ „	1846	3	46	150
„ „	1851	8	nil.	150
26. Croton, sp.	1844	21	30	50
27. Ricinus communis	1843	1	21	45
„ „	1845	3	15	45
„ „	1850	8	nil.	45
11. CORYLACEÆ.				
28. Fagus sylvatica	1846	1	78	300
„ „	1848	3	nil.	300
29. Quercus Robur	1845	3	3	30
„ „	1850	8	nil.	30
12. CUCURBITACEÆ.				
30. Momordica Elaterium	1845	3	13	75
„ „	1855	13	4	75
„ „	1857	15	nil.	75
31. Cucurbita Pepo	1843	1	35	45
„ „	1845	3	37	45
„ „	1850	8	19	45
„ „	1855	13	nil.	45
32. Bryonia dioica	1845	1	81	300
„ „	1847	3	5	300
„ „	1852	8	nil.	300
13. PASSIFLORACEÆ.				
33. Passiflora Herbertiana	1842	8	nil.	375
34. Tacsonia pinnatistipula	1842	6	nil.	150
14. VIOLACEÆ.				
35. Viola lutea	1844	1	202	450
„ „	1846	3	99	450
„ „	1851	8	1	450

Name.	Sown in	Age.	No. germinated.	No. sown.
14. VIOLACEÆ, *continued.*				
35. Viola lutea	1857	14	nil.	450
15. CRUCIFERÆ.				
36. Mathiola annua	1844	1	203	600
„ „	1846	3	236	600
„ „	1851	8	nil.	600
37. Turritis retrofracta	1842	6	nil.	1500
38. Arabis hirsuta	1848	4	36	200
39. „ lucida	1842	8	nil.	1500
40. Koniga maritima	1844	1	202	600
„ „	1846	3	170	600
„ „	1851	8	nil.	600
41. Lunaria biennis	1844	1	143	300
„ „	1846	3	114	300
„ „	1851	8	nil.	300
42. Vesicaria grandiflora	1845	1	299	450
„ „	1847	3	nil.	450
43. Iberis umbellata	1843	1	280	300
„ „	1845	3	150	300
„ „	1850	8	nil.	200
44. Biscutella erigerifolia	1844	1	21	300
„ „	1846	3	71	300
„ „	1851	8	nil.	300
45. Malcolmia maritima	1843	1	252	300
„ „	1845	3	178	300
„ „	1850	8	nil.	300
46. Hesperis matronalis	1844	1	222	300
„ „	1846	3	66	300
„ „	1851	8	2	300
„ „	1857	14	nil.	300
47. Erysimum Peroffskianum	1843	1	234	300
„ „	1845	3	82	300
„ „	1850	8	nil.	300
48. Lepidium sativum	1842	1	262	300
„ „	1844	3	195	300
„ „	1849	8	19	300
„ „	1854	13	nil.	300
49. Æthionema saxatile	1848	3	15	100
50. Isatis tinctoria	1848	4	15	100
51. Brassica Napus	1842	1	340	450
„ „	1844	3	323	450
„ „	1849	8	4	450
„ „	1854	13	nil.	450
„ oleracea	1842	1	67	150
„ „	1844	3	11	150
„ „	1849	8	nil.	150
„ „	1844	3	40	150*
„ „	1857	16	nil.	150
„ Rapa	1842	1	483	900
„ „	1844	3	335	900
„ „	1849	8	15	900
„ „	1854	13	nil.	900
52. Crambe maritima	1845	1	105	300
„ „	1847	3	6	300
„ „	1852	8	nil.	300
53. Bunias orientalis	1847	1	83	150
„ „	1849	3	57	150
„ „	1857	11	nil.	150

* (In waxed cloth.)

Name.	Sown in	Age.	No. germinated.	No. sown.
15. Cruciferæ, *continued.*				
54. Heliophila araboides	1844	1	275	600
„ „	1846	3	165	600
„ „	1851	8	nil.	600
55. Schizopetalon Walkeri	1846	1	96	150
„ „	1848	3	30	150
„ „	1853	8	2	150
„ „	1857	12	nil.	150
16. Capparidaceæ.				
56. Cleome spinosa	1844	1	126	300
„ „	1846	3	61	300
„ „	1851	8	nil.	300
17. Byttneriaceæ.				
57. Hermannia, sp.	1844	4	1	150
18. Tropæolaceæ.				
58. Tropæolum majus	1843	1	64	75
„ „	1845	3	52	75
„ „	1850	8	nil.	75
„ peregrinum	1848	2	15	30
59. Lymnanthes Douglasii	1846	1	91	150
„ „	1848	3	nil.	150
19. Malvaceæ.				
60. Malope grandiflora	1843	1	158	300
„ „	1845	3	127	300
„ „	1850	8	6	300
„ „	1855	13	nil.	300
61. Kitaibelia vitifolia	1848	4	23	200
62. Lavatera trimestris	1848	2	50	100
63. Malva mauritiana	1845	1	283	600
„ „	1847	3	281	600
„ „	1852	8	140	600
„ „	1857	13	13	600
„ sp.	1844	25	17	100
64. Hibiscus, sp.	1844	27	3	100
65. Sida, sp.	1844	25	75	150
20. Tiliaceæ.				
66. Corchorus, sp.	1844	27	2	50
67. Triumfetta, sp.	1844	25	30	75
21. Sapindaceæ.				
68. Cardiospermum Halicacabum	1848	1	59	75
„ „	1857	10	nil.	75
22. Hypericaceæ.				
69. Hypericum Kalmianum	1842	8	nil.	450
„ hirsutum	1844	1	8	450
„ „	1846	3	94	450
„ „	1851	8	nil.	450
23. Magnoliaceæ.				
70. Magnolia, sp.	1845	3	4	45
„ „	1850	8	nil.	45
71. Liriodendron tulipiferum	1843	1	1	50
„ „	1845	3	nil.	50
24. Ranunculaceæ.				
72. Clematis erecta	1842	6	nil.	150
73. Thalictrum minus	1847	1	62	300
„ „	1849	3	nil.	300
„ „	1849	1	57	600
„ „	1857	9	nil.	600
74. Anemone coronaria	1847	1	46	300
„ „	1849	3	nil.	300

Name.	Sown in	Age.	No. germinated.	No. sown.
24. Ranunculaceæ, *cont.*				
75. Adonis autumnalis	1843	10	86	150
„ „	1845	3	79	150
„ „	1850	8	7	150
„ „	1855	13	nil.	150
76. Ranunculus caucasicus	1847	1	9	300
„ „	1849	3	nil.	
77. Nigella nana	1843	1	110	150
„ „	1845	3	40	150
„ „	1850	8	nil.	150
78. Helleborus fœtidus	1845	1	63	450
„ „	1847	3	nil.	450
79. Delphinium flexuosum	1842	5	nil.	600
„ sp.	1848	6	1	200
80. Aconitum Napellus	1845	3	13	300
„ „	1850	8	12	300
„ „	1855	13	nil.	300
81. Pæonia, sps. mixt.	1842	1	?	300
„ „	1844	3	30	300
„ „	1849	8	nil.	300
25. Papaveraceæ.				
82. Argemone alba	1845	1	109	300
„ „	1847	3	159	300
„ „	1852	8	53	300
„ „	1857	13	nil.	300
83. Papaver amœnum	1843	1	179	300
„ „	1845	3	47	300
„ „	1850	8	nil.	300
„ orientale	1842	5	nil.	1500
84. Glaucium rubrum	1843	1	10	300
„ „	1845	3	47	300
„ „	1850	8	nil.	300
85. Eschscholtzia californica	1845	1	174	600
„ „	1847	3	124	600
„ „	1852	8	3	600
„ „	1857	13	nil.	600
86. Chryseis crocea	1842	5	4	300
„ „	1847	10	nil.	300
26. Fumariaceæ.				
87. Hypecoum procumbens	1842	6	nil.	150
88. Fumaria spicata	1846	1	98	300
„ „	1848	3	5	300
„ „	1853	8	nil.	300
27. Berberidaceæ.				
89. Berberis aquifolium	1842	7	nil.	60
28. Anacardiaceæ.				
90. Rhus, sp.	1844	4	7	50
29. Xanthoxylaceæ.				
91. Ailantus glandulosa	1846	1	63	150
„ „	1848	3	3	150
„ „	1853	8	8	150
„ „	1857	12	nil.	150
30. Linaceæ.				
92. Linum usitatissimum	1842	1	397	450
„ „	1844	3	202	450
„ „	1849	8	18	450
„ „	1854	13	nil.	450
„ perenne	1848	2	16	100
31. Balsaminaceæ.				
93. Balsamina hortensis	1846	6	81	150

Name.	Sown in	Age.	No. germinated.	No. sown.	Name.	Sown in	Age.	No. germinated.	No. sown.
31. Balsaminaceæ, *cont.*					37. Phytolaccaceæ.				
94. Impatiens glanduligera ...	1845	3	34	150	110. Phytolacca decandra	1844	1	35	75
„ „ ...	1850	8	11	150	„ „	1846	3	21	75
„ „ ...	1855	13	nil.	150	„ „	1851	8	nil.	75
32. Geraniaceæ.					38. Amarantaceæ.				
95. Pelargonium, sp.	1844	4	15	50	111. Amaranthus caudatus ...	1843	1	210	300
33. Caryophyllaceæ.					„ „ ...	1845	3	178	300
96. Buffonia annua	1843	1	109	300	„ „ ...	1850	8	1	300
„ „	1845	3	16	300	„ „ ...	1855	13	nil.	300
„ „	1850	8	nil.	300	39. Chenopodiaceæ.				
97. Cerastium perfoliatum ...	1848	1	14	300	112. Chenopodium Botrys......	1845	1	220	600
„ „ ...	1857	10	nil.	300	„ „	1847	3	nil.	600
98. Dianthus barbatus	1844	1	242	300	„ Quinoa ...	1849	2	171	600
„ „	1846	3	181	300	„ „ ...	1857	10	nil.	600
„ „	1851	8	2	300	113. Beta vulgaris	1846	1	146	215
„ „	1857	14	nil.	300	„ „	1848	3	155	215
99. Saponaria annua	1845	1	247	450	„ „	1853	8	23	215
„ „	1847	3	38	450	„ „	1857	12	nil.	215
„ „	1852	8	nil.	450	40. Saururaceæ.				
100. Gypsophila elegans	1844	1	140	600	114. Saururia, sp..................	1844	4	2	50
„ „	1846	3	143	600	41. Mesembryaceæ.				
„ „	1851	8	6	600	115. Mesembryanthemum cry-				
„ „	1857	14	nil.	600	stallinum	1843	1	53	300
101. Silene inflata	1844	1	58	150	„ „	1845	3	94	300
„ „	1846	3	88	150	„ „	1850	8	112	300
„ „	1851	8	2	150	„ „	1855	13	nil.	300
„ „	1857	14	nil.	150	42. Tetragoniaceæ.				
„ quadridentata	1848	2	31	100	116. Tetragonia expansa	1843	1	38	45
„ pendula	1848	2	41	200	„ „	1845	3	22	45
„ armeria alba	1848	3	31	100	„ „	1850	8	nil.	45
102. Viscaria oculata	1846	1	130	450	43. Thymelaceæ.				
„ „	1848	3	22	450	117. Gnidia, sp..................	1844	4	1	50
„ „	1853	8	9	450	44. Proteaceæ.				
„ „	1857	12	nil.	450	118. Leucadendron, sp.	1844	4	19	75
103. Pharnaceum, sp.	1844	4	3	100	45. Leguminosæ.				
34. Portulacaceæ.					119. Podalyria, sp................	1844	4	113	150
104. Talinum ciliatum	1844	1	196	600	120. Pultenæa, sp.	1844	21	2	100
„ „	1846	3	188	600	121. Lupinus lucidus............	1842	5	nil.	150
„ „	1851	8	5	600	„ rivularis	1842	5	1	75
„ „	1857	14	nil.	600	„ „	1847	10	nil.	75
105. Calandrinia grandiflora...	1842	5	58	600	„ polyphyllus	1842	6	1	300
„ „ ...	1847	10	nil.	600	„ „	1854	18	11	300
106. „ speciosa	1843	1	117	300	„ „	1857	21	nil.	300
„ „	1845	3	171	300	„ succulentus	1843	1	215	300
„ „	1850	8	18	300	„ „	1845	3	85	300
„ „	1855	13	nil.	300	„ „	1850	8	nil.	300
35. Polygonaceæ.					„ grandifolius......	1847	10	1	300
107. Polygonum Fagopyrum...	1842	1	61	150	„ „	1854	17	1	300
„ „ ...	1844	3	25	150	„ „	1857	20	nil.	300
„ „ ...	1849	8	7	150	122. Crotalaria, sp...............	1844	27	4	50
„ „ ...	1854	13	nil.	150	123. Aspalathus, sp.	1844	4	1	25
108. Rumex obtusifolium	1844	1	226	450	124. Ulex europæa	1843	1	36	300
„ „	1846	3	162	450	„ „	1845	3	113	300
„ „	1851	8	62	450	„ „	1850	8	17	300
„ „	1857	14	nil.	450	„ „	1855	13	66	300
36. Nyctaginaceæ.					„ „	1857	15	4	300
109. Mirabilis jalapa	1843	1	26	75	125. Spartium scoparium	1846	1	122	600
„ „	1845	3	30	75	„ „	1848	3	38	600
„ „	1850	8	nil.	75	„ „	1853	8	80	600

Name.	Sown in	Age.	No. germinated.	No. sown.
45. LEGUMINOSÆ, *cont.*				
125. Spartium scoparium	1857	12	3	600
126. Cytisus Laburnum	1843	1	80	150
" "	1845	3	21	150
" "	1850	8	2	150
" "	1855	13	nil.	150
" albus	1846	1	85	300
" "	1848	3	24	300
" "	1853	8	13	300
" "	1857	12	nil.	300
127. Tetragonolobus purpureus	1843	1	58	75
" "	1845	3	40	75
" "	1850	8	nil.	75
128. Trifolium repens	1842	1	119	450
" "	1844	3	22	450
" "	1849	8	nil.	450
129. Melilotus cærulea	1844	1	106	300
" "	1846	3	149	300
" "	1851	8	19	300
" "	1857	14	nil.	300
130. Trigonella fœnum-græcum	1843	1	122	150
" "	1845	3	89	150
" "	1850	8	nil.	150
131. Medicago maculata	1843	1	73	300
" "	1845	3	71	300
" "	1850	8	113	300
" "	1855	13	101	300
" "	1857	15	8	300
132. Ononis angustifolia	1842	6	nil.	300
133. Indigofera, sp.	1844	4	28	150
134. Psoralea bituminosa	1847	1	54	150
" "	1849	3	46	150
" "	1857	11	nil.	150
" sp.	1844	4	107	200
135. Galega, sp.	1844	26	16	100
136. Sutherlandia, sp.	1844	4	5	100
137. Colutea, sp.	1844	43	1	75
138. Pisum sativum	1842	1	92	150
" "	1844	3	94	150
" "	1849	8	15	150
" "	1854	13	nil.	150
139. Ervum, sp.	1846	4	90	100
140. Vicia sativa	1842	1	129	150
" "	1844	3	120	150
" "	1849	8	8	150
" "	1854	13	nil.	150
" grandiflora	1848	3	18	25
" lutea	1848	4	91	100
141. Faba vulgaris	1842	1	71	75
" "	1844	3	71	75
" "	1849	8	40	75
" "	1854	13	nil.	
142. Lathyrus heterophyllus	1843	1	44	150
" "	1845	3	105	150
" "	1850	8	63	150
" "	1855	13	1	150
" "	1857	15	nil.	150
" annuus	1848	2	21	25
" sativus	1848	3	6	6
143. Orobus niger	1845	3	18	150

Name.	Sown in	Age.	No. germinated.	No. sown.
45. LEGUMINOSÆ, *cont.*				
143. Orobus niger	1850	8	12	150
" "	1855	13	nil.	150
144. Scorpiurus sulcata	1843	1	59	75
" "	1845	3	22	75
" "	1850	8	nil.	75
145. Coronilla, sp.	1844	42	17	25
146. Æschynomene, sp.	1844	27	1	100
" "	1844	26	28	100
147. Hallia, sp.	1844	4	14	25
148. Hedysarum, sp.	1844	27	8	100
" "	1844	26	3	100
149. Clitoria, sp.	1844	26	2	20
150. Erythrina, sp.	1844	4	1	3
151. Phaseolus multiflorus	1842	1	67	75
" "	1844	3	47	75
" "	1849	8	1	75
" "	1854	13	nil.	75
" sp.	1844	25	25	25
152. Dolichos lignosus	1843	1	64	75
" "	1845	3	61	75
" "	1850	8	25	75
" "	1855	13	73	75
" "	1857	15	4	75
" sp.	1844	27	2	5
153. Cæsalpinia, sp.	1844	27	2	6
154. Cassia, sp.	1844	26	86	120
155. Tamarindus, sp.	1844	25	1	3
156. Cercis canadensis	1843	1	9	150
" "	1845	3	4	150
" "	1850	8	nil.	150
157. Gleditschia triacanthos	1846	1	87	90
" "	1853	8	3	90
" "	1857	12	nil.	90
158. Mimosa, sp.	1844	4	5	42
159. Adenanthera, sp.	1844	25	4	6
160. Robinia pseudacacia	1843	1	31	300
" "	1845	3	30	300
" "	1850	8	nil.	300
46. POMACEÆ.				
161. Cotoneaster rotundifolia	1843	1	2	20
" "	1845	3	16	60
" "	1850	8	nil.	60
162. Cratægus macrantha	1843	1	1	50
" "	1845	3	4	150
" "	1850	8	nil.	150
" punctata	1843	1	9	50
" "	1845	3	3	150
" "	1850	8	nil.	150
47. ROSACEÆ.				
163. Potentilla nepalensis	1842	7	nil.	900
" "	1843	1	49	300
" "	1845	3	52	300
" "	1850	8	nil.	300
" sp. from Douglas	1842	6	nil.	1200
164. Geum, sp.	1847	10	3	1500
" "	1854	17	nil.	1500
48. LYTHRACEÆ.				
165. Cuphea procumbens	1843	1	46	150
" "	1845	3	45	150

Name.	Sown in	Age.	No. germinated.	No. sown.
48. Lythraceæ, *cont.*				
165. Cuphea procumbens	1850	8	nil.	150
49. Rhamnaceæ.				
166. Trichocephalum, sp.	1844	4	2	25
167. Phylica, sp.	1844	4	1	17
168. Cryptandra, sp.	1844	21	9	50
50. Aquifoliaceæ.				
169. Ilex aquifolium	1843	1	2	300
" "	1845	3	nil.	300
51. Solanaceæ.				
170. Petunia odorata	1846	1	141	450
" "	1848	3	0	450
" "	1853	8	4	450
" "	1847	12	nil.	450
171. Datura Stramonium	1842	1	152	300
" "	1844	3	109	300
" "	1850	6	20	50
" "	1849	8	30	300
" "	1854	13	nil.	300
172. Hyoscyamus niger	1853	1	5	300
" "	1845	3	7	300
" "	1850	8	4	300
" "	1855	13	nil.	300
173. Capsicum, sp.	1843	1	56	75
" "	1845	3	33	75
" "	1850	8	nil.	75
174. Nicandra physaloides	1843	1	243	300
" "	1845	3	143	300
" "	1850	8	142	300
" "	1855	31	98	300
" "	1857	15	nil.	300
175. Solanum ovigerum	1845	1	140	600
" "	1847	3	0	600
" "	1852	8	12	600
" "	1857	13	nil.	600
176. Lycopersicum esculentum	1846	9	76	100
52. Asclepiadaceæ.				
177. Asclepias verticillata	1847	2	31	73
53. Convolvulaceæ.				
178. Convolvulus major	1844	1	29	150
" "	1846	3	41	150
" "	1851	8	9	150
" "	1857	14	1	150
54. Polemoniaceæ.				
179. Collomia coccinea	1843	1	135	300
" "	1845	3	64	300
" "	1850	8	nil.	300
180. Gilia achilleæfolia	1842	1	125	600
" "	1844	3	204	600
" "	1849	8	1	600
" "	1854	13	nil.	600
" capitata	1842	7	nil.	1500
181. Leptosiphon androsacea	1844	1	131	600
" "	1846	3	121	600
" "	1851	8	nil.	600
182. Polemonium gracile	1842	7	nil.	375
" cæruleum	1844	1	125	300
" "	1846	3	78	300
" "	1851	8	2	300

Name.	Sown in	Age.	No. germinated.	No. sown.
54. Polemoniaceæ, *cont.*				
182. Polemonium cæruleum	1857	14	nil.	300
183. Cobæa scandens	1845	2	3	9
" "	1850	8	nil.	9
55. Hydrophyllaceæ.				
184. Nemophila atomaria	1848	2	62	200
185. Eutoca viscida	1843	1	168	300
" "	1845	3	84	300
" "	1850	8	nil.	300
186. Phacelia tanacetifolia	1843	1	131	300
" "	1845	3	122	300
" "	1850	8	nil.	300
56. Plantaginaceæ.				
187. Plantago media	1844	1	120	450
" "	1846	3	130	450
" "	1851	8	nil.	450
57. Primulaceæ.				
188. Anagallis arvensis	1843	1	71	300
" "	1845	3	89	300
" "	1850	8	158	300
" "	1855	13	nil.	300
58. Nolanaceæ.				
189. Nolana atriplicifolia	1843	1	120	300
" "	1845	3	150	300
" "	1850	8	nil.	300
59. Boraginaceæ.				
190. Cerinthe major	1843	1	111	150
" "	1845	3	79	150
" "	1850	8	nil.	150
191. Echium grandiflorum	1844	1	201	300
" "	1846	3	135	300
" "	1851	8	nil.	300
192. Amsinckia angustifolia	1848	2	3	100
193. Cynoglossum glochidatum	1843	1	25	300
" "	1845	3	45	300
" "	1855	13	3	300
" "	1857	15	nil.	300
60. Labiatæ				
194. Elsholtzia cristata	1843	1	101	300
" "	1845	3	44	300
" "	1850	8	nil.	300
195. Horminum pyrenaicum	1842	7	nil.	150
196. Nepeta Cataria	1843	1	14	300
" "	1845	3	43	300
" "	1850	8	2	300
" "	1855	13	nil.	300
197. " citriodora	1848	2	3	100
198. Dracocephalum denticulatum	1847	3	24	260
199. Leonurus cardiaca	1843	1	165	300
" "	1845	3	78	300
" "	1850	8	5	300
" "	1855	13	nil.	300
200. Betonica hirsuta	1847	1	2	300
" "	1849	3	nil.	300
61. Verbenaceæ.				
201. Verbena Aubletia	1846	1	55	300
" "	1848	3	nil.	300

Name.	Sown in	Age.	No. germinated.	No. sown.
62. SELAGINACEÆ.				
202. Hebenstreitia tenuifolia ...	1844	1	175	300
,, ,, ...	1846	3	102	300
,, ,, ...	1851	8	nil.	300
63. PEDALIACEÆ.				
203. Martynia proboscidia ...	1843	1	27	60
,, ,, ...	1845	3	10	60
,, ,, ...	1850	8	nil.	60
64. BIGNONIACEÆ.				
204. Eccremocarpus scaber ...	1846	1	41	300
,, ,, ...	1848	3	3	300
,, ,, ...	1853	8	1	300
,, ,, ...	1857	12	nil.	300
205. Catalpa cordifolia	1843	1	11	50
,, ,, ...	1845	3	nil.	50
65. SCROPHULARIACEÆ.				
206. Browallia elata	1846	1	46	150
,, ,, ...	1848	3	6	150
,, ,, ...	1853	8	nil.	150
207. Chœnostoma polyantha ...	1848	1	5	300
,, ,, ...	1857	10	nil.	300
208. Schizanthus pinnatus......	1844	1	398	600
,, ,, ...	1846	3	240	600
,, ,, ...	1851	8	1	600
,, ,, ...	1857	14	nil.	600
209. Verbascum Thapsus	1842	1	430	500
,, ,, ...	1844	3	126	1500
,, ,, ...	1849	8	nil.	1500
210. Alonsoa incisa..............	1846	1	48	300
,, ,, ...	1848	3	5	300
,, ,, ...	1853	8	nil.	300
211. Linaria Prezii..............	1845	1	167	600
,, ,, ...	1847	3	1	600
,, ,, ...	1852	8	nil.	600
212. Linaria spartea	1848	3	3	100
,, bipartita	1848	3	6	100
213. Antirrhinum majus	1842	1	517	900
,, ,, ...	1844	3	475	900
,, ,, ...	1849	8	nil.	900
,, calycinum	1848	3	9	25
214. Collinsia heterophylla ...	1842	1	322	900
,, ,, ...	1844	3	578	900
,, ,, ...	1849	8	1	900
,, ,, ...	1854	13	nil.	900
215. Pentstemon diffusus	1842	6	nil.	900
,, pubescens ...	1842	6	nil.	1500
,, pulchellus ...	1842	6	nil.	750
,, atropurpureus	1842	6	nil.	750
,, digitalis	1842	6	nil.	900
,, lævigatus ...	1842	6	nil.	750
,, gracilis	1842	6	nil.	1500
,, procerus	1842	6	nil.	1200
216. Mimulus moschatus	1842	6	4	3000
217. Digitalis lutea..............	1843	1	213	300
,, ,, ...	1845	3	46	300
,, ,, ...	1850	8	nil.	300
218. Veronica peregrina.........	1847	1	34	300
,, ,, ...	1849	3	nil.	300
66. CAMPANULACEÆ.				
219. Campanula Medium	1844	1	125	300

Name.	Sown in	Age.	No. germinated.	No. sown.
66. CAMPANULACEÆ, *cont.*				
219. Campanula Medium	1846	3	109	300
,, ,, ...	1851	8	nil.	300
67. VALERIANACEÆ.				
220. Valeriana officinalis	1844	1	0	300
,, ,, ...	1846	3	17	300
,, ,, ...	1851	8	nil.	300
221. Fedia dentata	1850	5	3	50
68. DIPSACACEÆ.				
222. Dipsacus laciniatus.........	1843	1	63	150
,, ,, ...	1845	3	60	150
,, ,, ...	1850	8	nil.	150
223. Knautia orientalis	1846	1	39	150
,, ,, ...	1848	3	nil.	150
69. COMPOSITÆ.				
224. Ageratum mexicanum ...	1844	1	12	600
,, ,, ...	1846	3	135	600
,, ,, ...	1851	8	3	600
,, ,, ...	1857	14	nil.	600
225. Aster tenella	1844	1	184	600
,, ,, ...	1846	3	120	600
,, ,, ...	1851	8	nil.	600
226. Callistemma hortensis ...	1844	1	70	600
,, ,, ...	1846	3	161	600
,, ,, ...	1851	8	nil.	600
227. Stenactis speciosa	1843	1	113	300
,, ,, ...	1845	3	18	300
,, ,, ...	1850	8	nil.	300
228. Kaulfussia amelloides......	1844	1	181	300
,, ,, ...	1846	3	114	300
,, ,, ...	1851	8	1	300
,, ,, ...	1857	14	nil.	300
229. Buphthalmum cordifolium	1843	1	77	300
,, ,,	1845	3	26	300
,, ,,	1850	8	nil.	300
230. Zinnia multiflora	1844	1	0	450
,, ,, ...	1846	3	37	450
,, ,, ...	1857	14	nil.	450
,, grandiflora	1846	1	86	300
,, ,, ...	1848	3	2	300
,, ,, ...	1853	8	nil.	300
231. Sanvitalia procumbens ...	1845	1	154	600
,, ,, ...	1847	3	nil.	600
232. Rudbeckia amplexicaulis	1843	1	10	450
,, ,,	1845	3	55	450
,, ,,	1850	8	nil.	450
233. Coreopsis atrosanguinea...	1843	1	78	100
,, ,, ...	1845	3	142	300
,, ,, ...	1850	8	nil.	300
,, Atkinsoniana ...	1842	6	nil.	900
234. Helianthus indicus.........	1843	1	70	75
,, ,, ...	1845	3	68	75
,, ,, ...	1850	8	nil.	75
235. Bidens diversifolia.........	1844	1	39	450
,, ,, ...	1846	3	124	450
,, ,, ...	1851	8	2	450
,, ,, ...	1857	14	nil.	450
236. Tagetes patula	1848	3	20	200
,, lucida	1846	1	139	450
,, ,, ...	1848	3	5	450

Name.	Sown in	Age.	No. germinated.	No. sown.
69. Compositæ, *continued.*				
236. Tagetes lucida	1853	8	nil.	450
237. Gaillardia aristata	1846	1	87	300
" "	1848	3	nil.	300
238. Helenium Douglasii	1844	1	192	600
" "	1846	3	186	600
" "	1851	8	nil.	600
239. Callichroa platyglossa	1843	1	92	300
" "	1845	3	92	300
" "	1850	8	nil.	300
240. Galinsogea trilobata	1843	1	94	300
" "	1845	3	100	300
" "	1850	8	nil.	300
241. Sphenogyne speciosa	1843	1	157	300
" "	1845	3	75	300
" "	1850	8	nil.	300
242. Oxyura chrysanthemoides	1843	1	54	300
" "	1845	3	67	300
" "	1850	8	nil.	300
" "	1847	10	1	225
" "	1854	17	nil.	225
243. Madia splendens	1845	1	235	600
" "	1847	3	nil.	600
" "	1852	8	2	600
" "	1857	13	nil.	600
244. Cladanthus arabicus	1844	1	200	600
" "	1846	3	175	600
" "	1851	8	nil.	600
245. Lasthenia glabrata	1848	3	53	100
" californica	1842	1	343	600
" "	1844	3	363	600
" "	1849	8	4	600
" "	1854	13	nil.	600
" glabrata	1844	3	270	600*
" "	1857	16	nil.	600
246. Chrysanthemum coronarium	1846	1	172	450
" "	1848	3	122	450
" "	1853	8	3	450
" "	1857	12	nil.	450
247. Athanacea, sp.	1844	4	16	25
248. Ammobium alatum	1845	1	131	600
" "	1847	3	1	600
" "	1852	8	nil.	600
249. Xeranthemum annuum	1846	1	77	300
" "	1848	3	nil.	300
" "	1853	8	3	300
" "	1857	12	nil.	300
" "	1844	1	1	600
" "	1846	3	64	600
" "	1857	14	nil.	600
250. Calendula pluvialis	1842	1	256	600
" "	1844	3	401	600
" "	1849	8	nil.	600
" officinalis	1848	2	53	200
" maritima	1848	2	26	100
251. Arctotis, sp.	1844	4	48	100

Name.	Sown in	Age.	No. germinated.	No. sown.
69. Compositæ, *continued.*				
252. Centaurea depressa	1844	1	112	300
" "	1846	3	49	300
" "	1851	8	3	300
" "	1857	14	nil.	300
253. Centrophyllum tauricum	1848	3	11	25
254. Carthamus tinctorius	1845	1	106	300
" "	1847	3	44	300
" "	1852	8	nil.	300
255. Arctium Lappa	1844	1	16	300
" "	1846	3	64	300
" "	1851	8	3	300
" "	1857	14	nil.	300
256. Cnicus arvensis	1844	1	4	150
" "	1846	3	nil.	150
257. Rhagadiolus stellatus	1847	1	20	150
" "	1849	3	34	150
" "	1857	11	nil.	150
258. Catananche cærulea	1845	1	286	600
" "	1847	3	94	600
" "	1852	8	nil.	600
259. Cichorium Endivia	1843	1	228	450
" "	1845	3	260	450
" "	1850	8	139	450
" "	1855	13	nil.	450
260. Tragopogon porrifolium	1845	1	267	600
" "	1847	3	138	600
" "	1852	8	nil.	600
261. Aronopogon Dalechampii	1847	1	77	150
" "	1848	2	10	30
" "	1849	3	12	150
" "	1857	11	nil.	150
262. Scorzonera hispanica	1845	1	nil.	600
" "	1847	3	nil.	600
" "	1852	8	nil.	600
263. Picris echioides	1848	2	73	100
264. Lactuca sativa	1842	1	53	150
" "	1844	3	1	150
" "	1849	8	nil.	150
265. Borkhausia rubra	1844	1	131	300
" "	1846	3	196	300
" "	1851	8	2	300
" "	1857	14	nil.	300
" fœtida	1848	3	35	100
70. Onagraceæ.				
266. Œnothera tenella	1848	2	1	100
267. Œnothera, sp. from Douglas	1847	10	1	180
" "	1854	17	nil.	180
268. Godetia Lindleyana	1843	1	139	300
" "	1845	3	90	300
" "	1850	8	nil.	300
" lepida	1842	5	15	750
" "	1847	10	nil.	750
269. Clarkia elegans	1842	5	1	150
" "	1847	10	1	150
" "	1854	17	nil.	150

* (In open jar.)

Name.	Sown in	Age.	No. germinated.	No. sown.
70. ONAGRACEÆ, *cont.*				
270. Eucharidium concinnum	1844	1	110	600
" "	1846	3	256	600
" "	1851	8	nil.	600
271. Lopezia racemosa	1846	1	212	450
" "	1848	3	268	450
" "	1853	8	nil.	450
71. MYRTACEÆ.				
272. Eucalyptus, sp.	1844	21	1	20
72. LOASACEÆ.				
273. Loasa lateritia...............	1844	1	14	450
" "	1846	3	112	450
" "	1851	8	nil.	450
" nitida	1843	1	153	300
" "	1845	3	52	300
" "	1850	8	nil.	300
274. Bartonia aurea	1844	1	182	600
" "	1846	3	160	600
" "	1851	8	1	600
" "	1857	14	nil.	600
73. UMBELLIFERÆ.				
275. Petroselinum sativum ...	1842	1	94	150
" " ...	1844	3	42	150
" " ...	1849	8	1	150
" " ...	1854	13	nil.	150
276. Carum Carui	1845	1	334	600
" "	1847	3	2	600
" "	1852	8	nil.	600
" "	1849	8	2	600
" "	1854	13	nil.	600
277. Sium Sisarum...............	1845	1	73	600
" "	1847	3	nil.	600
278. Bupleurum rotundifolium	1843	1	21	300
" "	1845	3	67	300
" "	1850	8	nil.	300
279. Œnanthe crocata	1844	1	242	300
" "	1846	3	106	300
" "	1851	8	2	300

Name.	Sown in	Age.	No. germinated.	No. sown.
73. UMBELLIFERÆ, *cont.*				
279. Œnanthe crocata	1857	14	nil.	300
280. Æthusa cynapioides	1842	1	22	300
" "	1844	3	3	300
" "	1849	8	1	300
" "	1854	13	nil.	300
281. Fœniculum dulce	1847	1	192	300
" "	1849	3	84	300
" "	1857	11	nil.	300
282. Ligusticum Levisticum ...	1842	1	156	300
" " ...	1844	3	35	300
" " ...	1849	8	2	300
" " ...	1854	13	nil.	300
283. Angelica Archangelica ...	1844	1	19	300
" " ...	1846	3	47	300
" " ...	1851	8	nil.	300
284. Pastinaca sativa	1842	1	157	300
" "	1844	3	20	300
" "	1849	8	nil.	300
285. Heracleum elegans	1843	1	1	150
" "	1845	3	17	150
" "	1850	8	nil.	150
286. Daucus Carota	1842	1	155	300
" "	1844	3	79	300
" "	1849	8	1	300
" "	1845	8	37	900
" "	1847	10	nil.	900
" "	1854	13	nil.	300
287. Scandix brachycarpa	1848	3	95	150
288. Conium maculatum	1843	1	159	300
" "	1845	3	144	300
" "	1842	5	1	450
" "	1847	10	nil.	450
289. Smyrnium Olusatrum ...	1844	1	102	300
" " ...	1846	3	66	300
" " ...	1851	8	2	300
" " ...	1857	14	nil.	300

From the above summary, the accompanying Table, showing the greatest ages at which the seeds therein named were found to vegetate, has been prepared.

TABLE showing the Greatest Ages at which the Seeds named in the General Summary germinated.

Name.	Age.																	
	3	4	5	6	8	9	10	12	13	14	15	18	21	25	26	27	42	43
Graminaceæ.																		
Zea Mays	*																	
Phalaris canariensis	*	*	*	*	*													
Avena sativa	*	*	*	*	*													
Triticum æstivum	*																	
Secale cereale	*																	
Hordeum vulgare	*																	
Palmaceæ.																		
Phœnix dactylifera	*																	
Amaryllidaceæ.																		
Alstrœmeria pelegrina	*																	
Iridaceæ.																		
Gladiolus psittacinus	*																	
Iris sibirica	*																	
Tigridia Pavonia	*																	
Liliaceæ.																		
Allium fragrans	*	*	*	*	*													
Camassia esculenta	*	*	*	*	*	*	*											
Asphodelus luteus	*	*	*	*	*													
Asparagus officinalis	*																	
Coniferæ.																		
Pinus Pinea	*	*	*	*	*	*	*	*										
Betulaceæ.																		
Alnus glutinosa	*	*	*	*	*													
Cannabinaceæ.																		
Cannabis sativa	*	*	*	*	*													
Moraceæ.																		
Morus nigra	*																	
Euphorbiaceæ.																		
Euphorbia Lathyris	*																	
Croton, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*					
Ricinus communis	*																	
Corylaceæ.																		
Quercus Robur	*																	
Cucurbitaceæ.																		
Momordica Elaterium	*	*	*	*	*	*	*	*	*									
Cucurbita Pepo	*	*	*	*	*													
Bryonia dioica	*																	
Violaceæ.																		
Viola lutea	*	*	*	*	*													
Cruciferæ.																		
Mathiola annua	*																	
Arabis hirsuta	*	*																
Koniga maritima	*																	
Lunaria biennis	*																	
Iberis umbellata	*																	
Biscutella erigerifolia	*																	
Malcolmia maritima	*																	
Hesperis matronalis	*	*	*	*	*													
Erysimum Peroffskianum	*																	
Lepidium sativum	*	*	*	*	*													
Æthionema saxatile	*																	
Isatis, sp.	*	*																
Brassica Napus	*	*	*	*	*													
Brassica oleracea	*																	
Brassica Rapa	*	*	*	*	*													

Name.	Age.																
	3	4	5	6	8	9	10	12	13	14	15	18	21	25	26	27	42	43
Crambe maritima	*																	
Bunias orientalis	*																	
Heliophila araboides	*																	
Schizopetalon Walkeri	*	*	*	*	*													
Capparideæ.																		
Cleome spinosa	*																	
Byttneriaceæ.																		
Hermannia, sp.	*	*																
Tropæolaceæ.																		
Tropæolum majus	*																	
Malvaceæ.																		
Malope grandiflora	*	*	*	*	*													
Kitaibelia vitifolia	*	*																
Malva mauritiana	*	*	*	*	*	*	*	*	*									
Malva, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
Hibiscus, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Sida, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
Tiliaceæ.																		
Corchorus, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Triumfetta, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
Hypericaceæ.																		
Hypericum hirsutum	*																	
Magnoliaceæ.																		
Magnolia	*																	
Ranunculaceæ.																		
Adonis autumnalis	*	*	*	*	*													
Nigella nana	*																	
Delphinium, sp.	*	*	*	*														
Aconitum Napellus	*	*	*	*	*													
Pæonia, sp.	*																	
Papaveraceæ.																		
Argemone alba	*	*	*	*	*													
Papaver amœnum	*																	
Glaucium rubrum	*																	
Eschscholtzia californica	*	*	*	*	*													
Chryseis crocea	*	*	*															
Fumariaceæ.																		
Fumaria spicata	*																	
Anacardiaceæ.																		
Rhus, sp.	*	*																
Xanthoxylaceæ.																		
Ailantus glandulosa	*	*	*	*	*													
Linaceæ.																		
Linum usitatissimum	*	*	*	*	*													
Balsaminaceæ.																		
Balsamina hortensis	*	*	*	*														
Impatiens glanduligera	*	*	*	*	*													
Geraniaceæ.																		
Pelargonium, sp.	*	*																
Caryophyllaceæ.																		
Buffonia annua	*																	
Dianthus barbatus	*	*	*	*	*													
Saponaria annua	*																	
Gypsophila elegans	*	*	*	*	*													
Silene inflata	*	*	*	*	*													
Viscaria oculata	*	*	*	*	*													
Pharnaceum, sp.	*	*																
Portulacaceæ.																		
Talinum ciliatum	*	*	*	*	*													
Calandrinia speciosa	*	*	*	*	*													

Name.	Age.																	
	3	4	5	6	8	9	10	12	13	14	15	18	21	25	26	27	42	43
Polygonaceæ.																		
Polygonum Fagopyrum	*	*	*	*	*													
Rumex obtusifolium	*	*	*	*	*													
Nyctaginaceæ.																		
Mirabilis Jalapa	*																	
Phytolaccaceæ.																		
Phytolacca decandra	*																	
Amarantaceæ.																		
Amarantus caudatus	*	*	*	*	*													
Chenopodiaceæ.																		
Beta vulgaris	*	*	*	*	*													
Saururaceæ.																		
Saururus	*	*																
Mesembryaceæ.																		
Mesembryanthemum crystallinum	*	*	*	*	*													
Tetragoniaceæ.																		
Tetragonia expansa	*																	
Thymelaceæ.																		
Gnidia, sp.	*	*																
Proteaceæ.																		
Leucadendron, sp.	*	*																
Leguminosæ.																		
Pultenæa, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*					
Lupinus polyphyllus	*	*	*	*	*	*	*	*	*	*	*	*						
Crotalaria, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Aspalathus, sp.	*	*																
Ulex europæus	*	*	*	*	*	*	*	*	*	*	*							
Spartium scoparium	*	*	*	*	*	*	*	*										
Cytisus albus	*	*	*	*	*													
Melilotus cærulea	*	*	*	*	*													
Medicago maculata	*	*	*	*	*	*	*	*	*	*	*							
Psoralea bituminosa	*																	
Galega, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
Colutea	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Pisum sativum	*	*	*	*	*													
Vicia sativa	*	*	*	*	*													
Faba vulgaris	*	*	*	*	*													
Lathyrus heterophyllus	*	*	*	*	*	*	*	*	*									
Orobus niger	*	*	*	*	*													
Coronilla, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Æschynomene, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Hedysarum, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Clitoria, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
Phaseolus multiflorus	*	*	*	*	*													
Dolichos, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Cæsalpinia, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Cassia, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
Tamarindus, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
Gleditschia, sp.	*	*	*	*	*													
Adenanthera, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
Robinia	*																	
Pomaceæ.																		
Cotoneaster rotundifolia	*																	
Cratægus punctata	*																	
Rosaceæ.																		
Potentilla nepalensis	*																	
Geum, sp.	*	*	*	*	*	*	*											
Lythraceæ.																		
Cuphea procumbens	*																	
Rhamnaceæ.																		
Cryptandra, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*					

Name.	Age.																	
	3	4	5	6	8	9	10	12	13	14	15	18	21	25	26	27	42	43
Solanaceæ.																		
Petunia odorata	*	*	*	*	*													
Datura Stramonium	*	*	*	*	*													
Hyoscyamus niger	*	*	*	*	*													
Nicandra physaloides	*	*	*	*	*	*	*	*	*									
Solanum ovigerum	*	*	*	*	*													
Lycopersicum esculentum	*	*	*	*	*	*												
Convolvulaceæ.																		
Convolvulus major	*	*	*	*	*	*	*	*	*	*								
Polemoniaceæ.																		
Collomia coccinea	*																	
Gilia achilleæfolia	*	*	*	*	*													
Polemonium cæruleum	*	*	*	*	*													
Hydrophyllaceæ.																		
Eutoca viscida	*																	
Phacelia tanacetifolia	*																	
Plantaginaceæ.																		
Plantago media	*																	
Primulaceæ.																		
Anagallis arvensis	*	*	*	*	*													
Nolanaceæ.																		
Nolana atriplicifolia	*																	
Boraginaceæ.																		
Cerinthe major	*																	
Echium grandiflorum	*																	
Cynoglossum glochidatum	*	*	*	*	*	*	*	*	*									
Labiatæ.																		
Elsholtzia cristata	*																	
Nepeta cataria	*	*	*	*	*													
Leonurus cardiaca	*	*	*	*	*													
Selaginaceæ.																		
Hebenstreitia tenuifolia	*																	
Pedaliaceæ.																		
Martynia proboscidia	*																	
Bignoniaceæ.																		
Eccremocarpus scaber	*	*	*	*	*													
Scrophulariaceæ.																		
Schizanthus pinnatus	*	*	*	*	*													
Browallia elata	*																	
Verbascum Thapsus	*																	
Alonsoa incisa	*																	
Linaria Prezii	*																	
Antirrhinum majus	*																	
Collinsia heterophylla	*	*	*	*	*													
Mimulus moschatus	*	*	*	*														
Digitalis lutea	*																	
Campanulaceæ.																		
Campanula Medium	*																	
Valerianaceæ.																		
Valeriana officinalis	*																	
Fedia dentata	*	*	*															
Dipsacaceæ.																		
Dipsacus laciniatus	*																	
Compositæ.																		
Ageratum mexicanum	*	*	*	*	*													
Aster tenella	*																	
Callistemma hortensis	*																	
Stenactis speciosa	*																	
Kaulfussia amelloides	*	*	*	*	*													
Buphthalmum cordifolium	*																	

Name.	Age.																	
	3	4	5	6	8	9	10	12	13	14	15	18	21	25	26	27	42	43
Zinnia multiflora	*																	
Rudbeckia amplexicaulis	*																	
Coreopsis atrosanguinea	*																	
Helianthus indicus	*																	
Bidens diversifolia	*	*	*	*	*													
Tagetes lucida	*																	
Helenium Douglasii	*																	
Callichroa platyglossa	*																	
Galinsogea trilobata	*																	
Sphenogyne speciosa	*																	
Oxyura chrysanthemoides	*																	
Madia splendens	*	*	*	*	*	*												
Lasthenia californica	*	*	*	*	*													
Chrysanthenum coronarium	*	*	*	*	*													
Ammobium alatum	*																	
Xeranthemum annuum	*	*	*	*	*													
Calendula pluvialis	*																	
Centaurea depressa	*	*	*	*	*													
Carthamus tinctorius	*																	
Arctium Lappa	*	*	*	*	*													
Rhagadiolus stellatus	*																	
Catananche cærulea	*																	
Cichorium Endivia	*		*	*	*													
Tragopogon porrifolium	*																	
Arnopogon Dalechampii	*																	
Lactuca sativa	*																	
Barkhausia rubra	*	*	*	*	*													
Onagraceæ.																		
Œnothera, sp.	*	*	*	*	*	*	*											
Godetia lepida	*	*	*															
Clarkia elegans	*	*	*	*	*	*	*											
Eucharidium concinnum	*																	
Lopezia racemosa	*																	
Myrtaceæ.																		
Eucalyptus, sp.	*	*	*	*	*	*	*	*	*	*	*	*	*					
Loasaceæ.																		
Loasa lateritia	*																	
Bartonia aurea	*	*	*	*	*													
Umbelliferæ.																		
Petroselinum sativum	*	*	*	*	*													
Carum Carui	*	*	*	*	*													
Bupleurum rotundifolium	*																	
Œnanthe crocata	*	*	*	*	*													
Æthusa cynapioides	*	*	*	*	*													
Fœniculum dulce	*																	
Ligusticum levisticum	*	*	*	*	*													
Angelica Archangelica	*																	
Pastinaca sativa	*																	
Heracleum elegans	*																	
Daucus Carota	*	*	*	*	*													
Conium maculatum	*	*	*															
Smyrnium Olusatrum	*	*	*	*	*													

W. H. Baxter.

Oxford, 20th August, 1857.

Continuation of Report on Steam Navigation at Hull. By JAMES OLDHAM, *C.E. Hull, M.I.C.E.*

ON the occasion of the Meeting of the British Association at Hull in 1853, I had the honour of reading a short paper "On the Rise, Progress, and present Position of Steam Navigation at Hull," and thinking that a continuation of the subject might be interesting to the Association, to show the increase or advance which has taken place since 1853, I have prepared a second Report as a Supplement, which I beg now to present, but as it consists chiefly of Tables of Statistics, I shall only read to you the summary of the Tables, comparing them with those of 1853; before doing so, however, I will just refer to one other point introduced in my former paper, I allude to the facilities offered in the Port of Hull to iron ship-building. I then called upon ship-owners of that Port to encourage their fellow-townsmen in this important branch of art, and the result has been, that, since the Meeting of 1853, about fifty-six iron ships have been launched and completed, and by the end of the present year that number will be increased to sixty iron vessels of various descriptions, which will have been built in Hull by two houses, viz. Messrs. Charles and William Earle, and Messrs. Martin Samuelson and Co., in about four years,—varying in tonnage from about 1600 downwards, but producing an aggregate of about 27,000 tons burthen. Several of the above were built for other British Ports, and some for foreign Companies. The result is highly encouraging, and although a mere fraction of what has been effected throughout the United Kingdom, yet it illustrates the spirit which animates the determined and onward movement of commercial enterprise. Our builders too have made rapid improvements in both ships and machinery, and have proved, that, by following out the principles laid down by Mr. Scott Russell, the results will always be satisfactory. I may mention as a proof of this remark, that in one case a steam-ship of upwards of 1100 tons register, and only of 135 nominal horse-power, has made the passage from Cronstadt to Hull with a full cargo of goods, of upwards of 1500 tons weight, in $5\frac{1}{2}$ days.

It will be seen by the summary of the Tables of Statistics, compared with 1853, that there is under each head, except one, that of B, a great increase of steam shipping, viz.—A gives an increase of 10,564 tons and 2755 horse-power.——B a decrease of 1317 tons, and a decrease of 733 horse-power; but this is chiefly owing to some of the steamers having been placed in the list B, when they ought to have been in list D of 1853.——C gives an increase of 15,363 tons and of 3066 horse-power.——D gives an increase of 1275 tons and of 676 horse-power.

The total number of steamers, leaving out several tugs and other boats, but some of which were included in 1853, has increased from 81 to 131.

The total increase in tonnage is 25,885, and of horse-power 5764.

Tables of Statistics.

The following Tables show the present position of Hull in regard to the steamers which belong to, or trade from the Port:—(A.) Sea-going steamers belonging to the port. Total tonnage, 19,841; horse-power, 5554; averaging 3·57 tons per horse-power.——(B.) River steamers belonging to the port. Total tonnage, 901; horse-power, 402; averaging 2·24 tons per horse-power.——(C.) Sea-going steamers belonging to other ports, but trading to Hull. Tonnage, 21,272; horse-power, 5302; averaging 4·01 tons per horse-power.——(D.) River steamers belonging to other ports, but trading to Hull. Total tonnage, 2431; horse-power, 1102; averaging 2·20 tons per horse-power.

The total number of steamers trading to Hull amounts to 131, of the aggregate burthen of 44,445 tons, and 12,360 horse-power; averaging on the whole 3·60 tons per horse-power; giving also an average on the total number of steamers of 339·198 tons each.

Note.—68 screw and 63 paddle-steamers = 131.

(A.)—List of Sea-going Steamers belonging to the Port of Hull.

Name of Steamer.	Iron or Wood.	Paddle or Screw.	Tonnage. Builders.	Tonnage. Register.	Horse-power.	Proportion of tons to Horse-power.	Where and by whom built.	Engines where and by whom made.
Emperor	Iron	Paddle	1320	914	400	3·30 to 1	Robert Napier, Glasgow	Robert Napier, Glasgow.
Lion	Iron	Paddle	1073	716	400	2·68 to 1	Brownlow and Co., Hull	David Napier, Glasgow.
Queen of Scotland	Wood	Paddle	619	435	150	4·12 to 1	Duffles and Co., Aberdeen	Butterley Company, Aberdeen.
Helen M'Gregor	Iron	Paddle	601	435	230	2·61 to 1	John Laird, Birkenhead	Forrester and Co., Liverpool.
Eagle	Iron	Screw	628	423	100	6·28 to 1	Brownlow and Co., Hull	Brownlow and Co., Hull.
Transit	Wood	Paddle	497	331	140	3·55 to 1	Pearson and Co., Thorne	Fenton and Co., Leeds.
Swanland	Iron	Screw	480	347	100	4·80 to 1	Napier and Crichton, Glasgow	Napier and Crichton, Glasgow.
Gazelle	Wood	Paddle	402	269	100	4·02 to 1	Murris and Co., Greenock	Caird and Co., Greenock.
Emerald Isle	Wood	Paddle	410	270	150	2·73 to 1	Motteshead and Co., Liverpool	Preston and Co., Liverpool.
Prince	Iron	Paddle	379	290	100	3·79 to 1	Brownlow and Co., Hull	Thos. Wingate and Co., Whiteinch.
Albatros	Wood	Paddle	248	176	90	2·75 to 1	Edward Gibson, Hull	Brownlow and Co., Hull.
Fairy	Iron	Screw	164	111	60	2·73 to 1	T. D. Marshall, South Shields	T. D. Marshall and Co., South Shields.
Iris	Wood	Paddle	158	96	45	3·51 to 1	Henry Smith, Gainsborough	Brownlow and Co., Hull.
Sea-Gull	Iron	Paddle	564	355	240	2·35 to 1	Coates and Young, Belfast	Coates and Young, Belfast.
Ocean Queen	Iron	Screw	219	175	50	4·38 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Irwell	Iron	Screw	572	441	110	5·20 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Falcon	Iron	Screw	477	347	86	5·54 to 1	Denney, Brothers, Dumbarton	Fullock and Denney, Dumbarton.
Humber	Iron	Screw	535	399	100	5·35 to 1	A. Denney, Dumbarton	Fullock and Denney, Dumbarton.
Burlington	Iron	Screw	452	369	80	5·65 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Hawk	Iron	Screw	427	329	100	4·27 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Lord Cardigan	Iron	Screw	467	364	80	5·83 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Secret	Iron	Screw	310	239	50	6·20 to 1	Denney Brothers, Dumbarton	Caird and Co., Greenock.
Alert	Iron	Screw	258	175	62	4·16 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Martlet	Iron	Screw	249	169	50	4·98 to 1	Brownlow and Co., Hull	C. and W. Earle, Hull.
North Sea	Iron	Screw	614	417	120	5·11 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Moscow	Iron	Screw	578	461	80	7·22 to 1	Palmer Brothers, Newcastle	R. Hawthorne and Co.
Sea Horse	Iron	Screw	492	335	120	4·10 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Emmeline	Iron	Screw	501	394	80	6·30 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Kingston	Iron	Screw	372	300	70	5·31 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Tiger	Iron	Screw	651	442	150	4·34 to 1	Brownlow and Co., Hull	Brownlow and Co., Hull.
Wesley	Iron	Screw	500	396	70	7·14 to 1	Richardson and Duck, Stockton	Thompson and Wood.
Pacha	Iron	Screw	405	283	60	6·75 to 1	Hoby and Co., Renfrew	Hoby and Co., Renfrew.
Atlantic	Iron	Screw	1308	1111	135	9·68 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.

Velocity	Iron	Screw	259	176	60	4·31 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Vigilant	Iron	Screw	259	176	60	4·31 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Helena	Iron	Screw	237	181	30	7·90 to 1	Geo. Cram, Chester	Geo. Cram, Chester.
Cheviot	Iron	Screw	190	154	40	4·75 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Alster	Iron	Screw	485	299	120	4·04 to 1	Denney and Rankins, Dumbarton	Neilson and Co.
Sydenham	Iron	Screw	461	313	80	5·76 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Enchantress	Iron	Screw	250	170	70	3·71 to 1	Blackwood and Gordon, Paisley	Blackwood and Gordon, Paisley.
Swallow	Iron	Screw	360	290	70	5·14 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Corkscrew	Iron	Screw	205	160	26	7·88 to 1	Ditchburn and Mare, London	Beale, Greenwich.

(B.)—List of River Steamers belonging to the Port of Hull.

Pelham	Wood	Paddle	113	60	40	2·82 to 1	H. Smith and Sons, Gainsborough	James Overton, Hull.
Middlesbro'	Wood	Paddle	68	22	38	1·78 to 1	North Shields	Marshall, South Shields.
Wilberforce	Wood	Paddle	67	23	36	1·86 to 1	Andrew Bell, North Shields	J. E. Harrison, North Shields.
Eliza	Wood	Paddle	54	20	29	1·86 to 1	Gateshead	Hawks, Gateshead.
Fairing	Wood	Paddle	37	17	12	3·08 to 1	J. Dowey, North Shields	Jas. and John Wait.
Joseph and Elizabeth	Wood	Paddle	46	13	22	2·09 to 1	Stephenson and Maxwell, N. Shields	Thomas Ellis.
William and John	Wood	Paddle	79	24	38	2·07 to 1	Wm. Cooper, North Shields	John P. Almond.
Pilot	Wood	Paddle	53	17	28	1·89 to 1	Wm. Cooper, North Shields	John P. Almond.
Wave	Wood	Paddle	77	59	30	2·56 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
James Watt	Wood	Paddle	88	30	40	2·20 to 1	North Shields	
Eagle (Yacht)	Wood	Screw	13	9	12	1·08 to 1	James M'Ardle, Liverpool	Williams and Mould.
Frolic	Wood	Screw	10	7	3	3·33 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Chesapeake	Wood	Paddle	64	40	25	2·56 to 1	Thorbon and Grant, North Shields	Hepple and Sandells.
Empress	Iron	Paddle	67	42	24	2·79 to 1	Charles and Langley, Rotherhithe	Miller and Ravenhill.
Champion	Wood	Paddle	65	41	25	2·60 to 1		

(C.)—*List* of Sea-going Steamers trading to Hull, but belonging to other Ports.

Leipsig	Iron	Paddle	700	497	250	2·80 to 1	Liverpool	Liverpool.
Neptune	Wood	Paddle	253	173	100	2·53 to 1	Thompson & Pearson, South Shields	T. D. Marshall.
Jupiter	Wood	Paddle	425	288	220	1·93 to 1	Scott, Sinclair, and Co., Greenock	Scott, Sinclair, and Co., Greenock.
Vivid	Wood	Paddle	368	228	180	2·04 to 1	Curling and Young, London	Seaward and Co., London.
Waterwitch	Wood	Paddle	415	275	180	2·30 to 1	Curling and Young, London	Seaward and Co., London.
Glen Albyn	Wood	Paddle	284	189	110	2·58 to 1	Scott, Sinclair, and Co., Greenock	Scott, Sinclair, and Co., Greenock.
Bold Buccleuch	Iron	Paddle	200	145	120	1·66 to 1	Smith and Rogers	Smith and Rogers.

(C.)—List of Sea-going Steamers trading to Hull, but belonging to other Ports (continued).

Name of Steamer.	Iron or Wood.	Paddle or Screw.	Tonnage. Builders.	Tonnage. Register.	Horse-power.	Proportion of tons to Horse-power.	Where and by whom built.	Engines where and by whom made.
Britannia (F.)	Iron	Screw	465	347	120	3·87 to 1	T. D. Marshall and Co., S. Shields	T. D. Marshall and Co., S. Shields.
Hammonia (F.)	Iron	Screw	384	310	80	4·80 to 1	T. D. Marshall and Co., S. Shields	T. D. Marshall and Co., S. Shields.
Archimedes (F.)	Iron	Screw	326	263	80	4·07 to 1	T. D. Marshall and Co., S. Shields	T. D. Marshall and Co., S. Shields.
Sea Nymph	Wood	Paddle	166	105	60	2·76 to 1	William Furley, Gainsborough	J. Overton and Co., Hull.
Urania (F.)	Iron	Screw	519	460	120	4·32 to 1	T. D. Marshall and Co., S. Shields	T. D. Marshall and Co., S. Shields.
Forager	Wood	Paddle	86	52	56	1·53 to 1	Furley and Co., Gainsborough	Thompson and Stather, Hull.
Minister Thorbeck (F.)	Iron	Screw	275	200	60	4·57 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Graaf van Rechteren (F.)	Iron	Screw	203	146	50	4·06 to 1		
Burgeemeester Huidekooper (F.)	Iron	Screw	221	171	50	4·42 to 1		
Gouveneur van Euyck (F.)	Iron	Screw	221	171	50	4·42 to 1		
Engineer	Iron	Paddle	253	159	120	2·10 to 1	David Napier, Glasgow	D. Napier, Glasgow.
Norfolk	Iron	Paddle	284	201	120	2·36 to 1	Ditchburn and Mare, London	Caird and Co., London.
Queen	Iron	Paddle	472	343	140	3·37 to 1	Wilson and Son, Liverpool	Fawcett and Co.
Hamburg	Iron	Paddle	767	532	250	3·06 to 1	Robert Napier, Glasgow	R. Napier, Glasgow.
Oscar	Iron	Screw	472	345	120	3·93 to 1	Russell and Co., London	Russell and Co., London.
Prince of Wales	Iron	Screw	627	356	100	6·27 to 1	W. Simons and Co., Whiteinch	Inglis and Co., Whiteinch.
Blarney	Iron	Screw	252	208	30	8·40 to 1	Cork Ship Building Company	Bury, Curtis, and Kennedy.
Powerful	Iron	Screw	861	658	120	7·17 to 1	T. D. Marshall and Co., S. Shields	T. D. Marshall, South Shields.
Gothenburg	Iron	Screw	454	331	100	4·54 to 1	Scott Russell and Co., London	Scott Russell and Co., London.
Spurn	Iron	Screw	439	344	80	5·48 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Gertrude	Iron	Screw	469	374	80	5·86 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Propeller	Iron	Screw	658	456	120	5·48 to 1	T. D. Marshall and Co., S. Shields	T. D. Marshall, South Shields.
Cygnus	Iron	Paddle	286	180	110	2·60 to 1	J. Henderson and Sons, Renfrew	Macnab and Clarke, Greenock.
Volga	Iron	Screw	239	194	40	5·97 to 1	Richardson & Sons, Stockton on Tees	Richardson & Sons, Stockton on Tees.
Collier	Iron	Screw	152	103	40	3·80 to 1	J. Reid, Glasgow	Caird and Co.
Antelope	Iron	Screw	901	612	150	6·00		Forrester and Co.
Lord Ashley	Iron	Screw	422	387	80	5·27 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Grimsby	Iron	Screw	651	442	100	6·51 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Lord Worsley	Iron	Screw	414	281	80	5·17 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Lucien	Iron	Screw	504	343	80	6·30 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
St. George	Iron	Screw	437	369	60	7·28 to 1	C. Mitchell, Newcastle	R. Morrison, Newcastle.
Daniel (F.)	Iron	Screw	164	84	60	2·73 to 1	Blackwood and Gordon, Paisley	Blackwood and Gordon, Paisley.

Yarborough	Iron	Screw......	[illegible]	441	100	[illegible] to 1	M. Samuelson and Co., Hull........	M. Samuelson and Co., Hull.
Iberia........................	Wood......	Paddle ...	515	301	190	2·71 to 1	Curling and Young, London	Miller and Ravenhill.
William France............	Iron	Screw......	403	281	60	6·71 to 1	J. W. Hoby and Co., Renfrew	J. W. Hoby and Co., Renfrew.
Levant	Wood......	Paddle ...	694	395	280	2·48 to 1		Caird and Co., Greenock.
Scandinavian...............	Iron	Screw......	423	253	106	3·99 to 1	Thos. Wingate and Co., Whiteinch	Thos. Wingate and Co., Whiteinch.
Courier	Iron	Paddle ...	373	245	140	2·66 to 1	Thos. Wingate and Co., Whiteinch	T. Wingate and Co., Whiteinch.
St. Petersburg	Iron	Screw......	578	460	80	7·22 to 1	Palmer Brothers, Newcastle	R. Hawthorne and Co.
De Caters (F.)	Iron	Screw......	398	270	100	3·98 to 1	C. and W. Earle, Hull	C. and W. Earle, Hull.
Ganger Rolf (F.)	Iron	Screw......	500	380	100	5·00 to 1		
Queen	Iron	Screw......	220	175	50	4·40 to 1		
Aberdeenshire	Iron	Screw......	230	180	50	4·60 to 1		

Note.—Those steamers with the letter (F.) belong to foreign parts.

(D.)—List of River Steamers trading to Hull, but belonging to some other Port.

Ariel	Iron	Paddle ...	158	70	28	5·64 to 1	T. and W. Pimm, Hull	John Linton, Selby.
Eagle........................	Iron	Paddle ...	124	85	60	2·06 to 1	Aire and Calder Co., Goole	B. Hawthorne and Co.
Atalanta	Iron	Paddle ...	123	90	40	3·07 to 1	H. Smith and Sons, Gainsborough...	Penn and Sons, Greenock.
Harlequin	Iron	Paddle ...	113	85	40	2·82 to 1	H. Smith and Sons, Gainsborough...	Penn and Sons, Greenock.
Columbine..................	Iron	Paddle ...	85	55	40	2·12 to 1	Smith and Sons, Gainsborough......	Penn and Sons, Greenock.
Ebor	Wood......	Paddle ...	89	62	35	2·54 to 1	Smith and Sons, Gainsborough......	Aydon and Reid, Wakefield.
City of York	Iron	Paddle ...	84	65	38	2·21 to 1	John Linton, Selby......................	John Linton, Selby.
Judith	Wood......	Paddle ...	43	11	25	1·72 to 1	T. D. Marshall, South Shields	T. D. Marshall, South Shields.
Expedition..................	Wood......	Screw......	23	18	8	2·87 to 1	Joseph Sleigh Brigg, Hull	T. and W. Pimm, Hull.
Manchester	Iron	Paddle ...	190	141	90	2·11 to 1	M. Samuelson and Co., Hull.........	M. Samuelson and Co., Hull.
Sheffield....................	Iron	Paddle ...	201	161	90	2·23 to 1	M. Samuelson and Co., Hull	M. Samuelson and Co., Hull.
Falcon	Wood......	Paddle ...	90	57	35	2·57 to 1		James and John Wait.
Magna Charta	Wood......	Paddle ...	87		28	3·10 to 1		James and John Wait.
Laurel	Wood......	Paddle ...	19	13	4	4·75 to 1	J. Wandby, York	Jeremiah Wandly, York.
Endeavour..................	Wood......	Paddle ...	54	21	28	1·92 to 1	North Shields	James and John Wait.
Peep-o'-day-boy	Wood......	Paddle ...	40	13	20	2·00 to 1	J. P. Almond, North Shields.........	J. P. Almond, North Shields.
Queen (York)	Iron	Paddle ...	83	63	35	2·37 to 1	Potts, North Shields	W. Scott.
Sir C. Campbell	Iron	Paddle ...	119	65	75	1·58 to 1	J. Barr, Glasgow.......................	T. Barr, Glasgow.
Fury	Wood......	Paddle ...	46	19	27	1·70 to 1	Hepple and Langdale, North Shields	Hepple and Langdale, North Shields.
Speedwell	Iron	Paddle ...	35	20	16	2·18 to 1	R. Wilkinson, Boston...................	Howden and Sons, Boston.
Royal Albion..............	Wood......	Paddle ...	91	36	40	2·27 to 1	Parkinson and Co., Hull...............	Overton and Wilson.
(Old) Manchester........	Iron	Paddle ...	290	174	150	1·93 to 1	Robinson and Russell, London	Robinson and Russell, London.
(New) Sheffield...........	Iron	Paddle ...	244	148	150	1·62 to 1	H. Smith and Sons, Gainsborough...	G. and J. Rennie, London.

Report of a Committee, consisting of The Rt. Hon. Earl of HARDWICKE, Chairman; Mr. ANDREW HENDERSON, Mr. JOHN SCOTT RUSSELL, Mr. JAMES ROBT. NAPIER, Mr. CHARLES ATHERTON, Mr. ARTHUR ANDERSON, Rev. Dr. WOOLLEY, Admiral MOORSOM (vice Mr. W. MANN), Mr. JOHN MACGREGOR (vice Mr. G. F. YOUNG), Captain J. O. OWEN, Professor BENNETT WOODCROFT, JAMES PERRY, *and* Mr. JAMES YATES, Secretary, *appointed to inquire into the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships**.

THE Committee, having held its sittings weekly, for the purposes of inquiry and the reception of information, beg leave to present the following Report:—

Your Committee think it necessary, at the outset, to state the difficulties they met with (incidental, no doubt, to all private committees that attempt to inquire into laws affecting particular classes) in inducing individuals to appear before them to give evidence on this subject, or to give information by writing or correspondence.

The *chief* information now derived is from members of the Committee, who, being personally interested in the subject, were naturally biassed in their views by the circumstances that surround them.

The mode, therefore, your Committee thought it best to adopt, for the purpose of eliciting information, was that of circulating the annexed letter (see No. I. in Appendix), specially referring to eight points of inquiry bearing on the subjects.

Copies of this Circular were sent to the Admiralty, Navy Board, Board of Trade, Custom House, and Treasury, with a request that copies might be forwarded to the various *Officers* under *Government* connected with the *scientific* and *working departments*.

Your Committee received from all the Government Departments *a refusal* to forward those questions.

Copies of the Circular were also sent to all the Local Marine Boards, to the offices of the public newspapers, at shipping ports, and to many gentlemen connected with *science* and trade.

The Local Marine Boards declined to entertain the question.

Answers were returned from several individuals, including members of your Committee.

Your Committee proceed to give a short summary of the replies, which they received from their own members, and which are inserted in the Appendix.

Mr. John Scott Russell considers the object of registered tonnage is the taxation of their contents; the present is a mere standard of taxation! that all tonnage dues should be abandoned, and the same should be levied on freight.

For scientific purposes, he considers that the register tonnage measurement cannot be of any service—does not consider that it would be tolerated, that

* See Report for 1856, p. 458.

lines of construction and scientific calculations should be demanded to be given up under an Act of Parliament.

Considers (on the question of steam power) that it would be neither politic nor expedient to attempt to define power in a form more absolute than the nature of the subject practically admits.

The results of his reflections are, that nothing is necessary to be now done except to rectify the allowance for engine room, which remains fictitious and arbitrary.

Dr. Woolley thinks it hopeless to look for information from legislative enactments that would be useful in a scientific point of view.

Thinks that in the levying of dues on shipping it is impossible to devise a general rule fairer than that which is now in force.

Does not think the public much interested in the question.

Does not doubt that the more science is brought to bear in shipbuilding the greater will be the economy, both as regards the first cost and the management of vessels; and owners will consequently be able to charge a lower price for carrying goods and passengers.

Considers that an enforced registration should have for its object—

1st. To secure a fairness in levying Government dues.

2ndly. To give a fair idea of the amount of tonnage or roomage employed for mercantile purposes.

Thinks the present registration sufficient for merely statistical purposes.

Thinks the present law makes too great a difference between steamers and sailing ships.

Sees no valid reason for making distinctions based on the different materials of which ships are built, or making discriminative distinctions between vessels based on the different principles of machinery with which they may be fitted.

He agrees with Mr. Napier in thinking an enforced registration of engine-power needless.

Mr. James Robert Napier considers the objects of registration to be the levying of dues, and simplifying the process of transferring the property from one owner to another.

Thinks the present system of tonnage measurement is more minute than is necessary, and of little or no use to the shipbuilder; is inclined to take Mr. Russell's view of the subject, and not limit the load-draft of water.

Does not see any reason for making a distinction between vessels built of wood or iron.

Considers nominal horse-power a useless term. Instead of nominal horse-power, he would substitute simply the capacity of the cylinders, or area of cylinders, multiplied by length of stroke. This would be positive information, and would be useful in buying and selling, and might be inserted in the registry of a vessel.

Thinks a legal standard of power would remove some confusion which at present exists.

Mr. Atherton considers that the present registration of shipping, as respects tonnage and nominal horse-power, affords no definite measure of quantity, either as to ship or engines, available for judging of the relative capabilities of steam ships.

Thinks the statistics of trade, based on the present expression of "tonnage," does not indicate the amount of trade, as respects the weight of goods conveyed.

Considers that there is no constant ratio between "*Tons Burden*" and

"*Tons Register*," and the capability for carrying *tons weight of cargo*; and therefore the present official registration does not fulfil the advertising requirements of trade.

Considers that no definition of tonnage, and no mode of determining it, can adequately embrace both the capability of a ship for carrying *weight* and its capacity for holding *bulk*. The weight-tonnage and the bulk-tonnage must therefore be distinct.

Considers that, as the present scheme of registration does not set forth any of the principal dimensions, as length, breadth, and depth, or the load-line-draught, or give the displacement either at light-draught when ready to receive cargo, or at the load-draught or submerging-draught, it cannot, on any definite principle, constitute the base of scientific inquiry into the comparative displacement and consequent dynamic performances and merits of ships, nor a reliable base for statistical inquiry into the imports and exports of the country.

Does not consider that the science of naval architecture would be interfered with by the constructor's deep draught of water forward and aft, or some regulation limit to be assigned as such, being made an item in the official registration of every ship, and duly marked on the ship herself.

Considers that, in forming a rule for placing this mark to regulate the freeboard limit, an investigation into existing practice (as to the *ratio which actually exists between the freeboard and the length, breadth, and depth of the hull*) will be the best means of deducing a rule for determining the position of the mark in question. Proposes a rule to exemplify this method of determining the freeboard limit.

Considers that, if the registration be based on admeasurements comprehensively adequate for deducing therefrom the *weight*-tonnage and *bulk*-tonnage, then no occasion will exist for discriminative protection in favour of any particular class of vessel, whether sailing-ship or steamer, or description of material with which a ship may be built, or systems of machinery by which ships may be propelled.

Considers the present registration of engine-power a delusion, because no definite measure of power has been assigned, either by the legislature or by the practice of trade, to the term "Nominal Horse-power," as indicating the working-power of marine engines.

Considers that a legalized unit of horse-power is a requirement only of secondary importance to a comprehensive tonnage registration.

Considers there can be no objection to a system prescribed by law, whereby ships are to be measured for tonnage registration, to include their capability for carrying weight, in addition to the bulk-tonnage prescribed by the present law, and considers that all official admeasurements should be made on one uniform principle, to be sanctioned by scientific authority. Shows that weight-tonnage would assimilate closely with metrical tonnage.

Admits Sterling's rule, as prescribed for the measurement of ships, by the Act of 1854, to be based on strictly scientific principles, but regards its practical application as inconvenient, and not self-detective of error, and a pirating of the lines of ships.

Considers Mr. Peake's system, for various reasons stated, as the best for common use in determining cubical admeasurements, whereby the roomage and tonnage of a ship may be ascertained and registered, without affording data for pirating the constructor's lines.

Mr. Henderson states the objects of registering tonnage; gives a table that shows the mode that has been in use, and the measurements for ascer-

taining displacements at certain specified draughts that are in addition desirable; gives a proposed form of certificate.

Considers the plan of measurement (at present used under the Act of 1854) practically inefficient for obtaining a correct mensuration of vessels, in consequence of equal divisions not being always attainable.

Considers that, to obviate certain defects (stated in his paper given in the Appendix, No. 6), all measurements, besides that of the measuring officers, should be attested by the builder and owner, &c.

Considers that, after a trial of two years, the present tonnage measurement and registration system has proved deficient and non-effective for the attainment of most of the objects of public utility which registration ought to afford.

Gives a comparison of four modes of measurement, on paper ruled to a scale, $\frac{1}{4}$ inch to a foot, for facilitating the process of admeasurement.

Thinks that the book of instructions given to measuring surveyors should contain practical directions and diagrams of each of these four modes of measurement.

Thinks that the measuring officers should be shipbuilders or nautical men, experienced in taking measurements.

Admiral Moorsom is of opinion that every vessel should incur a penalty which is loaded so as to sink below a certain draught of water.

That her registered tonnage should comprise the weight of water between her assigned load-draught and that draught which she would have when fit for sea, with crew and stores and everything on board, except that by which she earns her freight.

He proposes a plan for obtaining the results required for registration*.

Considers that the public have great concern in the improvement of engines, and improvement can make but slow and fitful progress when the *power exerted* and *power given out* are not known.

Considers that any measure of power must be incomplete without the weight of fuel which is the originator of the power, and in any general system for the registration of engine capability we must include the constructive details of the boiler as well as the cylinder.

Such an expression would mean a given weight moved through a certain space in a certain time with a certain weight of coal.

Admiral Moorsom forwarded also a pamphlet, by himself, bearing on this subject, which will be found in the Appendix.

Mr. James Yates shows the points of agreement between the party, as represented by Mr. Moorsom, Registrar-General of Tonnage, and that represented by those who consider the present system of registration imperfect. Recommends the adoption of the "Metrical Ton" as the base of a ship's registered tonnage.

The foregoing is a brief summary of the answers given to the eight questions circulated by your Committee, which were received from members of the said Committee, and will be found in the Appendix to this Report.

Letters from Mr. James Peake and Admiral Laws, bearing on the subject, were received.

That from Mr. Peake gives a full explanation of his method of calculating the tonnage of ships, both internally and externally.

Your Committee have also received answers from gentlemen connected with Science and Trade to the effect, as follows:—

* Appendix, No. 7.

Mr. Mansel considers that the registration of the carrying capability of a vessel should be viewed in reference to weight alone, and is strictly proportional to her external volume between the load and light-draught water-lines, but has no definite relation to the capacity inside of the inner lining.

Considers that, at the commencement, the desire to foster the growth of steam-shipping led to the adoption of a discriminating tonnage, to an extent injurious towards sailing vessels, and erroneous in principle.

Considers that the capacity sacrificed to *fuel* alone ought to have been exempted from dues.

Thinks that the difference between the displacement at the *light*-draught and the displacement at the *load*-draught, would be the weight-carrying capability of the ship for cargo and stores, in the case of a sailing vessel, and for cargo, fuel, and stores, in the case of a steam-ship; and that it is imperative that this difference should be registered, even though *it might not* be taken as the basis for levying dues.

Considers that the present law for measuring ships is objectionable, inasmuch that it does not directly imply the external volume of the vessel upon which the carrying capability, cost of construction, and propulsion, directly depend. Also, supposing *equal strength*, it is our interest that the difference between the external and internal volume shall be a minimum. At present, with equal displacement, the vessel with this difference greatest *pays least dues, and thus an indirect premium is given to the worst ship.* Again, the method of allowing engine deduction is still more objectionable, for if we fill a certain portion of the internal volume with an inefficient mechanism, we get the same deduction from gross tonnage, as if the same portion of the same vessel had been filled with the most perfect mechanism, working up to a much greater power, to the disadvantage of the better mechanised ship.

Considers that nominal horse-power implies a certain area of piston moving through a certain space, &c. Indicated horse-power has no very definite relation to the above. The first represents more nearly the commercial value of the material and workmanship; the second, the evaporative power of boiler, fuel, and cost of working, &c.

Thinks that the simplest divisor for indicating horse-power, in foot lbs. per minute, should be 100,000. Sees no objection to retaining the old and well-known unit of 33,000 foot lbs. per minute equal to one-horse power, and thinks it absolutely essential that both nominal horse-power and indicated horse-power should be defined and recognized by legal enactment, and form part of the registered elements of ships—the first, or engine register of nominal horse-power, being essential for the valuation of the engine, and the second, or indicated power, for the working expenses of the engine.

Mr. Greenhow thinks it would be of great value to acquire a true estimate of the capability for carrying weight of cargo, and advances his reasons for so thinking:—

Scientifically.—The register ought to be a decided gauge, by which to ascertain her capability for carrying weight of cargo.

Statistically.—The returns of tonnage now published afford no criterion by which to judge of the amount of produce conveyed.

Considers that the present system of tonnage measurement, as prescribed by the Merchant Shipping Act of 1854, gives very incorrectly "the internal roomage of ships."

Sees no difficulty in a change towards truth, in re-arranging the tonnage dues, by which no greater amount will be paid by the shipowner.

Thinks there ought to be a limit to the amount of lading.

States that he has established a rule, by which to establish the position of the light and load line, suited to the varying dimensions of different ships.

He gives the plan of his rule.

Mr. Lawrie does not think that any restriction should be laid on the draught of water in a ship, but that it should be left in the hands of the insurers. Thinks a radical change should be made in the mode of measuring engine-power.

Mr. Schöneijder finds that he has been foiled in his search for knowledge in England, as regards the size and tonnage of ships, as well as their engine-power; the present system of registration giving him no information on this important subject.

Mr. Miller thinks that the present rule (Sterling's) is sufficient for all purposes of measurement, and gives correct data for whatever measurements may be required; yet he considers that, in addition to the same, there should be supplied a correct scale of displacement; also the proper position of the centre of gravity of displacement; centre of effort of sails, and the length of the meta-centre, or centre of stability;—thereby determining the ship's proper trim.

Does not think it equitable or advisable to make a discriminative distinction (to the extent given by the present law) between sailing ships and steamers.

Thinks it desirable that some definite system be adopted that might determine the actual working-power of steam-engines for marine purposes.

Mr. Baxter writes on the loss of ships at sea, and thinks that the capability of a ship to convey a cargo safely through the sea is in no way defined, or capable of being judged of, by the present system of tonnage.

Mr. Henry Wright states that, in 1839, before a Committee of Inquiry into the cause of the Wrecks of Timber Ships, it was found that in 1836–7–8, out of 5427 vessels which cleared from British North America, there was an aggregate loss of 226, or 4·164 per cent. by wreck, of which upwards of 150 were at sea, the remainder being wrecked on shore. It was remarked that there were lost as many *good* as *bad* ships, showing that the frailty of the vessels was not the sole cause, but owing to improper over-stowage. The result was "*interference*," and the loss was reduced *one-half*.

Mr. Wright demonstrates the weakness of the present law to *prove* the overloading of a ship, and that insurance offers no safeguard whatever.

Mr. George Rennie states that he agrees generally in the views of Mr. Atherton.

Your Committee, having duly weighed the character of the evidence, and the opinions given therein, are of opinion,—1st, That the present method of measuring and registering the tonnage of shipping, gives a very close approximation to the internal capacity of a ship; but that it gives no measure of the power of a ship to carry weight.

2ndly. Engine Power (Horse-power), though an item of registration, yet has no practically definite or *legalized signification*, as a measure of marine-engine capability for working power; no unit of power is given, and there are no registered data by which the working capability of an engine can be approximately ascertained.

Your Committee differ in opinion as to the capability of ships for carrying weight being made an item of registration, but if one denomination of tonnage only is to be recognized, concur in the opinion that "tonnage" (though a misnomer as applied to space) should be continued, as under the present law, to be based on the internal roomage of ships. Consider it

F 2

incompatible with the principles of unrestricted competition to make arbitrary discriminations, in the measurements for tonnage, between vessels built of timber or iron, or fitted with the paddle or the screw (c. 22 and 23), for the following reasons:—

The internal capacity of iron ships (ships built upon the cellular principle, like the 'Great Eastern') has not necessarily a greater ratio to the external bulk, than is the case with wooden ships (ships built on the diagonal plank principle, like the 'Nankin,' 'Niger,' and 'Banshee'); but the very reverse may be the case, and the space required for the machinery of a screw-ship, of given power, is not necessarily either greater or less than the space so occupied by engines of the same power constructed for a paddle-wheel vessel.

Then, again, the law, in its present discriminations between the paddle and the screw, does not meet the case of the paddle and the screw combined (as in the 'Great Eastern'), or, indeed, any other combination.

It therefore appears to your Committee, that discriminations, as regards the material of which ships are built, or different mechanical contrivances by which ships are propelled, *should be abolished.*

As regards the discriminations between sailing vessels and steamers (section 23), whereby, in certain cases, steamers propelled by paddle are allowed 37 per cent., and when by screw, 32 per cent., to be deducted from the gross tonnage, in consideration of the space occupied by machinery, which arbitrary deduction gives no consideration to space *actually appropriated to engine room*, or to the *actual power or weight* of the machinery, without which consideration such space may be occupied by cargo, this discrimination, and the mode of assessing it, appears to your Committee devoid of principle, and not just even between steamers themselves. For example, a sailing vessel and a steamer may be of the same gross tonnage (say 1000 tons), but in consequence of the steamer being fitted with auxiliary machinery, not weighing possibly more than 100 tons, including coals, there is, by law, in the special cases now referred to, a reduction from its tonnage of 37 per cent., or 370 tons; and again, the reduction of the steamer's tonnage may be 370 tons, whether the weight of the machinery and coals be actually 100 or 500 tons.

That in making a deduction for propelling-machinery and fuel, the deduction for tonnage based on space, as by the present law, should be rated *on actual space occupied*; and as respects tonnage based on weight, the reduction would in effect be rated on the weight of machinery, the same being included in the light-displacement, which would be deducted from the load-displacement.

Your Committee, considering that the question of Government dues or private dues assessed on shipping is a question between parties in the state (which, though indirectly bearing on this inquiry, yet is not put to your Committee as a question for their consideration and report), does not feel itself called upon in the Report to enter into its merits.

On the subject of Engine Power, your Committee cannot find that any statute *unit of power* has ever been recognized in any legislative enactment for fixing standard units of quantity (such as the standard yard, gallon, pound-weight, &c.). The registration of horse-power is prescribed by the Act of 1854, but *no legalized definition* is given of the *term* as a measure of mechanical power, nor has the term "Nominal Horse-power" any definite signification in trade as a measure of working power; and consequently the registration of the engine-power of a steam-ship affords no certain indication of her engine capabilities.

It is found in practice that the actual working-power of marine engines, with reference to their nominal horse-power, fluctuates upwards of 100 per cent., and on the general *average* of the practice of the present day, it appears that the unit of marine engine horse-power is equivalent to 100,000 lbs. raised one foot high per minute of time, being equal to three times the unit denominated "Indicated Horse-power" (viz. 33,000 lbs. raised one foot high per minute).

It appears to your Committee that the legalization by statute of some standard unit of power is an indispensable requirement of the age; and the question is, whether 33,000 lbs. or 100,000 lbs. raised one foot high per minute, shall be recognized and legalized as the standard unit of power to which the registration of marine engine-power should have reference.

That the unit designated by 100,000 lbs. raised one foot high per minute, would nearly approach the working capability per nominal horse-power of the present marine engines, is admitted; but conceiving that a registration of engine capability would still not give all the information as to the engines which registration ought to embrace, your Committee recommend that *the registration of marine engines should, in addition to their capability, embrace the number and diameter of the cylinders, and length of stroke, or other indication of the size of engine, according to its construction, as well as the number and size of the boilers, and total area of the fire-grates,* whereby the size and quantity of the machinery on board, irrespective of its capability for working power, may be at any time compared with the registered description thereof.

The Committee supposed it important to confine the Report to those points on which *a definite and almost unanimous opinion could be given.* With respect to the question relating to the registration of weight-tonnage and displacement, after maturely considering the evidence, the Committee *did not agree in such a manner* as to be able to recommend this portion of the subject for legislative enactment.

(By order of the Committee) HARDWICKE,
May 27, 1857. *Chairman.*

APPENDIX.

No. I.—CIRCULAR.—*To the respective Members of the Committee appointed by the British Association "to inquire into the defects of the present methods, and to frame more perfect rules for the Measurement and Registration of Ships and of Marine Engine Power, in order that a correct and uniform principle of estimating the actual Carrying Capabilities and Working Power of Steam Ships may be adopted in their future Registration."*

SIR,—Rear-Admiral the Right Honourable the Earl of Hardwicke having been nominated by the members of the Tonnage Committee, "to officiate as permanent chairman for conducting (with the assistance of a private secretary, whom his Lordship may be pleased to nominate) the proceedings of this Committee," his Lordship has directed me as Secretary (*pro tem.*) to request that the members of this Committee will be pleased to meet at the Hall of the Society of Arts, Adelphi, London, on Thursday, 1st January next, at eight o'clock P.M., to take into consideration the business assigned to this Committee, especially with a view to concerting as to the points of statistical inquiry on which this Committee may require to avail themselves of the co-

operative assistance of the Statistical Section of the British Association, in accordance with the recommendation and resolution of the General Committee of the British Association to that effect.

Preparatory to this meeting on Thursday, the 1st January, and in order that the opinions of each of the members of the Committee, whether present or not, may be known and duly noticed, it is requested that each member will be pleased to communicate in writing, on or before Monday, 1st December next, addressed to "The Secretary of the Tonnage Committee, Society of Arts, Adelphi, London," his opinions on the following points, and on such other points as may especially occur to respective members in relation to the matters submitted by the British Association for the consideration of this Committee:—

1. To particularize the objects of public utility, fiscal, mercantile, scientific, and statistical, sought to be attained, or which may be promoted by a complete system of measurement, and comprehensive registration of the tonnage capabilities of ships, and the engine capabilities of steam ships.

2. Admitting that the present system of tonnage admeasurement, as prescribed by the Merchant Shipping Act of 1854, giving the *internal roomage* of ships, affords useful data for registration so far as it goes, what are the additional details of admeasurement which are required to give the capability of ships for carrying *weight of cargo*, and in other respects necessary to render the official registration of shipping, as periodically published by authority in the Mercantile Navy List, complete and effective for the objects of public utility above referred to?

3. To particularise in what respects the present system of tonnage and engine-power admeasurement and registration, as prescribed by Part 2 of the Merchant Shipping Act of "1854," is deficient and not effective for the attainment of the objects of public utility above referred to.

4. Following the example of limitations commonly prescribed by Government in matters wherein public safety is concerned, such, for example, as protection from fire in Building Acts, what are the objections to the official assignment of some limit to the load-draught of water, based on ordinary conditions of protection from wreck, at which ships may leave port; and presuming on the necessity for some limit being assigned which the draught of water may not exceed, by what rules may this limit be most correctly determined, and by what regulations may it be most effectually enforced without involving unnecessary interference with mercantile shipping transactions?

5. In what respects is it commercially equitable, or in other respects advisable, to make a discriminative distinction between sailing ships and steamers in the measurement of the registered tonnage on which dues may be charged on shipping?

6. In what respects is it commercially equitable, or in other respects advisable, in the measurement and calculation of registered tonnage, to make a discriminative distinction, based on the different materials (whether wood or iron, or a combination of both) with which ships may be built, or on the different principles of machinery (whether paddle-wheels, screw-propeller, paddle and screw combined, water-jet, or other appliance) with which ships may be fitted?

7. Seeing that no definite measure of power has been specifically fixed by law as the statute unit of mechanical power (as has been done to regulate all other measures of quantity, as in the cases of the statute yard, the statute acre, the statute gallon, the statute pound, &c.), and seeing, moreover, that in the practice of trade, the "nominal horse-power" of a steam-ship does not

define the measure of power available for the propulsion of the ship (the capability of engines for the production of working power with reference to their nominal horse-power being notoriously, in some cases, the double of what it is in others), what steps should be taken to remedy this incongruity; and, presuming on its being determined to adopt some specific measure of power as the legalized standard unit of power, what definition, measure, or amount of power, should (in the opinion of the respective members of this Committee) be adopted as the statute unit of marine engine-power, and by what *name* should it be called, viz. whether "horse-power," or "marine horse-power," or "statute-power," or "units of power," or other denomination?

8. The respective members of Committee are requested to state their opinion whether it be advisable that any particular mode of prosecuting the details of measurement and working out the calculations thereof (such, for example, as Sterling's rule) should be prescribed by law for the measurement of ships, as is done by the Merchant Shipping Act of "1854;" or, ought the system of taking the measurements and working out the calculations to be left to the discretion of the chief officer of the department on whom the responsibility for the scientific prosecution and accuracy of the calculations will professionally rest, as in the case of the astronomical calculations for the Nautical Almanac published by Government, but for which the system of prosecuting the observations and deducing the calculations is not prescribed by law, but determined and improved from time to time, as may be, by the astronomer; and if it be considered that a prescribed mode of working out the calculations ought to be fixed and enforced by law, is the rule (Sterling's) now enforced by the Merchant Shipping Act the best rule now known and practised for calculating the cubature of ships?

It is not expected that the respective members of this Committee will individually express opinions on each and all of the various points above submitted for their consideration, but it is requested that each member, according to his special avocation, experience, or acquirements, will address himself to those points on which he may be regarded as an authority; and as the complete elucidation of the matters referred to this Committee, with a view to the public good, is the duty assigned to this Committee, it is requested that each member will not only express his own opinion, but seek information and confer with others within his sphere conversant with the matters referred to, though not members of this Committee; and for the purpose of aiding in this object of obtaining information, duplicate copies of the points of investigation above propounded are enclosed herewith.

It is further purposed, that as soon as the written opinions or answers of the respective members of the Committee, to be given in on or before Monday, the first day of December, shall be received by the Secretary, addressed as above directed, copies thereof will be forwarded to each of the members of this Committee for mutual information, and in order that further confirmation, or correction, or amendment of the original opinions, may be thus elicited, to constitute the base of the general report to be discussed and settled at a future meeting of this Committee, preparatory to being presented to the British Association at their ensuing meeting.

I am, Sir, your obedient Servant,
CHARLES ATHERTON,
Secretary, *pro tem.*

Woolwich Dockyard, Nov. 6, 1856.

No. 2.—Mr. J. SCOTT RUSSELL (*Member of the Committee*).

1st, 2nd, 3rd. The original object of legislation for tonnage appears to

have been the taxation of their contents. A keel of coals was a vessel of given size, carrying a given bulk and weight of coals. The present imperial tonnage scale is still a mere standard of taxation. It is, however, much more common to tax the ship according to this imperial tonnage, than to levy the tax on her contents, as originally intended. Taxation by tonnage is, therefore, arbitrary; to distribute taxation, or to exact tonnage dues equitably, they should be levied on the actual freight or cargo, and not on the mere vehicle which conveys them. If this were done, the present tonnage-laws might be altogether repealed, or retained for statistical purposes merely. It would tend much to the promotion of the commerce of this country, if shipping were thus emancipated from the present inequitable restrictions, by the abandonment of all tonnage dues and tonnage registration for "*fiscal purposes*." Dues for lights and harbours, if levied on actual freights and cargoes, would be much more equitably, and not less efficiently, levied than at present. I agree with Mr. Napier in thinking this the best solution of all the difficulties connected with the tonnage question.

If this were done, register tonnage would remain as a mere record of the internal capacity, or of the room inside of ships, an imperial ton being retained, as now, to indicate a space of 100 cubic feet, or a space of 5 feet, by 5 feet, by 4 feet. Such measure, used for mere *statistical purposes*, would be unobjectionable.

For *mercantile purposes*, that is, for chartering or hiring ships, the present law is most convenient. The bulk of the room which the charterer hires, and the owner receives payment for, is measured with sufficient precision for such practical purposes.

For *scientific purposes*, at least for purposes of naval architecture, it does not appear to me that anything of the nature of register tonnage or measurement can be of any service. The construction plans, or lines of a ship given by a shipbuilder, with all the elements of her construction, if combined with a record of her performance, and an authentic account of her sailing qualities, would be of great value. Anything short of this, recording some of her elements, and excluding others, would be more likely to mislead than inform. Shape is a principal element in the performance of a ship, and the lines of the ship are required adequately to give that. I do not think that it would be tolerated in this country by shipbuilders that their lines of construction and scientific elements and calculations should be demanded to be given up under certain clauses by Act of Parliament; neither, if this difficulty were overcome, could records of qualities be obtained compulsorily, to give the compulsory elements of construction—the scientific value which they would only obtain by an equally compulsory record of performance. Careful experiments, made by individuals or associations, can alone be expected to afford scientific data of this nature.

4. The example of Government interference in such matters, is so bad an example, that it should be avoided rather than followed, in imposing restrictions on the shipping trade. There is no reason to regard the Government of our country as either more interested in enabling a ship to perform her journey safely, or more able to judge of the conditions of such safety, than her captain and her owner. As every different form of ship, and every different quality of ship, and various species of cargo and each different voyage would admit of, and require, a different degree of loading—this must be left to the captain and owner, who know their ship and their business, instead of being consigned to officers who cannot know it.

5. It is a mistake to suppose that, in giving to steam-ships an exemption from payment of tonnage dues on their engine-room and coal-bunkers, they

are obtaining a preference over sailing vessels. On the contrary, it is essential to fairness that such exemption should be given. Sailing ships already possess such exemption in the existing tonnage-law. The divisor 100, in the tonnage-law, gives that exemption. The real ton of freight is 40 cubic feet in most things, and, in some, 50 feet. The difference between the mercantile ton of 40 feet, and the imperial register ton of 100 feet, is designed to give the shipowner ample exemption for that portion of the internal room of a ship which is occupied by captain's cabins, sailors' berths, sails, cables, cordage, chains, anchors, sea-stores, provisions, and all the requisites of mooring and working the ship. This exemption has been recognized in all the tonnage-laws of this country. It has been merely extended to the steam-ship on the same footing—the propelling power, and all provisions for it, being included in a similar exemption. The error of the present law consists in making that exemption on an arbitrary tonnage, instead of the actual tonnage of engine room—an error which no time should be lost in remedying.

6. I do not see, and cannot imagine, why any exemption should be made other than that of the actual room occupied by engines, boilers, and fuel.

7. The only true measure of power is the work actually performed by a marine engine; this work will vary with the talent of the maker, with the care and intelligence of the keeper of the engine, with the age and condition of the boiler, and with the qualities and loading of the ship. In the absolute sense of true power, two engines, in which all the main dimensions are alike, and both perfectly new, will give out a totally different practical result. This is why the engine of one maker is well worth £60 per horse-power, and of another not worth £30. Yet, under varying circumstances, a given engine will perform double at one time from another.

Owing, therefore, to the great variety in kinds and qualities of engines, it is neither politic nor expedient to attempt to define power in a form more absolute than the nature of the subject practically admits. The scale commonly used among engineers for buying and selling engines is just as good as any other, so long as the talent of the builder and the knowledge of the uses is a main element of power of a marine engine. It is a question of name and character more than of dimensions and measure. Legislation cannot safely try to trammel such elements.

8. Practically, Sterling's rule, or Attwood's rule, or Chapman's rule, or any ordinary intelligent rule, will tell very accurately the cubic contents of the inside of a ship. I do not see any grave fault in the present rule, though I will not assert that some more minutely precise rule for purposes of abstract science might not be given.

Conclusion.—The result of considerable thought and pains given to this examination is that, in my opinion, we need not ask any alteration of the law regulating Imperial Register Tonnage, except the rectification of the allowance for engine-room, which remains fictitious and arbitrary. Neither should I recommend any further interference of Government officers with the registration or working of ships or steam-vessels. I look for the advancement of naval architecture rather to the association of naval constructors and men of science with each other, and the mutual communication of their notions and knowledge, than to empirical efforts of legislation; and I hope for progress in navigation, rather from the general advancement of education and knowledge, among all who are concerned in shipping, than from any trammels which, in the disguise of assistance and regulation, Government might be induced to impose on the captains and owners of ships.

February 17, 1857.

No. 3.—Rev. Dr. Woolley (*Member of the Committee*).

To the Hon. Secretary of the Tonnage Committee.

Portsmouth Dockyard, Feb. 27, 1857.

Sir,—I regret that so few members of the Committee have put us in possession of their opinions on the subjects on which we have to report; especially that no actual builder of ships has given us the benefit of his experience.

As regards the report, I am of opinion that we should keep in view two objects:—1. The particularising of the useful objects which an interchange between shipbuilders of information with regard to ships actually built by them, might be expected to produce. 2. Those objects which an enforced registration ought to attain.

1. On a careful consideration of the whole subject, I have embraced the decided opinion that it is hopeless to look for such information as would be useful in a scientific point of view from legislative enactment. There are so many points beside light and load displacement, indicated horse-power, &c., which must be known in order to form a sufficient scientific estimate of the value of a ship, that I fear an enforced registration of certain particulars would be found to be a delusion. Our scientific objects can best be attained by the voluntary association of persons interested in shipbuilding and the science of naval architecture. If the British Association would lend the sanction of its authority to the recommendation of the institution of a Naval Architectural Society, it would, I think, be conferring a greater boon on science than by any other means.

Legislative interference is very much to be deprecated, except to serve an object in every way commensurate with the evils which all restrictions impose upon trade. We cannot too jealously guard against unnecessary restraints, and should be very chary of calling for Government assistance. The well-known maxim of Horace applies with great force to legislative interference with matters of this kind—

> Nec Deus intersit nisi dignus vindice nodus
> Inciderit.

I cannot say that it appears to me that any adequate object has been proposed in the various answers to the eight queries of which I have received an abstract. On one point all seem agreed, viz. that absolute fairness in the incidence of tolls can only be secured by charging in every case on the actual freight. Short of this, and if it be not feasible to make the actual freight the basis of levying the dues, then I am of opinion that it is impossible to devise a general rule fairer than that which is now in force.

I cannot see that the public are much interested in this question. The ownership of ships is in a sufficient number of hands to protect the public from anything like a monopoly, and to render the application of the principles of supply and demand secure. The competition existing among shipowners is a sufficient security that the carriage of goods will be fixed at the lowest remunerative price. No doubt the more science is brought to bear on shipbuilding the greater will be the economy, both as regards the first cost and the management of vessels, and owners will consequently be able to charge a lower price for the carriage of goods and passengers. But I do not think that the application of science is to be sought by legislative enactment.

2. An enforced registration would have for its object—First, to secure fairness in levying Government dues (in case dues should continue to be levied on tonnage); and secondly, to give a fair idea of the amount of ton-

nage or roomage, or whatever it may be called, employed for mercantile purposes. The space available at the usual rate of 40 cubic feet to a ton, is quite sufficient for the purpose ; and as the internal roomage divided by 100 does on the average bear a definite ratio to this space, I am inclined to think that the present registration is sufficient for merely statistical objects.

Among the reasons which have weighed most with me, in arriving at the above conclusions, are the following :—

In all the rules which have been established by Act of Parliament for the measurement of tonnage, the legislature has had one object in view, viz. to provide for the fair incidence of tolls.

If measurement by weight were taken as the basis of registration, external measurement, as proposed by the Tonnage Committee of 1849, viz. up to the deck, would not be more correct than the present legalized internal measurement; and it would have the disadvantage of offering an inducement to build ships of insufficient strength—as the greater the ratio of the internal to the external capacity for the greater number of cargoes, the more advantageous would the arrangement be to the owner. It is generally acknowledged that a comparatively large interior space or roomage, is of principal importance in the eyes of shipowners; and that it would not be a recommendation generally, that, with a small internal capacity, a vessel possessed large capacity for carrying weight. If, therefore, the registration were based on external measurement, it would become the interest of the owner to reduce the scantling of the vessel to the lowest possible dimensions—even verging upon danger.

The 'Great Eastern,' now building at Millwall, will have a large external displacement compared with its internal roomage, owing to its being built on the cellular principle. I cannot think this an advantage, viewed merely in a commercial or economical point of view, as the prime cost is greater, and the vessel when built is not as available for the ordinary run of merchandise as others which have a proportionably larger internal roomage.

The strength of a vessel is a very important element in its construction; and it appears to me that the registration of tonnage for dues on the external instead of the internal measurement up to the deck would operate greatly to the detriment of this element.

The carriage of passengers cannot be considered as among the least lucrative of the uses to which a ship may be put. The room required for each passenger is out of all proportion greater than the weight of himself and luggage. Passenger ships, with a comparatively small displacement, require large internal roomage; and as all covered spaces are included in the present internal measurement, the incidence of dues is far more just on the present law than it would be on a law which established a system of mere external measurement.

It has been urged that the prevalence of shipwrecks and consequent loss of life must be laid to the door of the present defective state of shipping registration. I do not, however, find that the result of the inquiries of persons most competent to judge corroborates this view. Among the causes which the seamen themselves (no incompetent judges) urge, such as the enormous competition of late years, insufficiency and incompetency of crews and officers, I do not find the overloading of ships. I cannot but infer from this significant silence that such a cause is not in operation, at least to any considerable extent.

To appreciate the qualities of a vessel in a scientific point of view, a knowledge of the light and load displacements, as well as of the area of midship section, and of the form of the ship, especially towards the bows and stern,

is absolutely indispensable. The qualities of the vessel, as shown at sea, are also necessary elements to forming this estimate. Of these none but the load and light displacements have been proposed to become the subjects of registration; and these alone would by no means supply that information which must form the basis of all scientific estimate.

External measurements up to the deck, as proposed by the Commission of 1849, would afford no data for obtaining a knowledge of the light and load displacement. The first requisite for this purpose is to fix a definite load water-line. The impracticability of defining such limit, openly avowed by one Royal Commission, has been felt and acted on by all. There is no rule of science which can establish it—it is always to a certain extent a matter of judgment, and it varies not only with every different condition of lading and trim, but also with the season of the year. It may be, or it may not be, that a rule for the defining of free-board, in other words, the distance between the load water-line and the deck, expressed in definite parts of the principal dimensions, may answer tolerably well for the actual practice, with regard to a considerable proportion of our present mercantile navy; but such a rule can be nothing but the merest empiricism, would certainly not satisfy a majority of persons at present interested in shipping, and might be found absolutely inapplicable to vessels built on some improved principle, which not only may, but probably will, be introduced into naval architecture within a few years. The fixing of the load water-line on other than strictly scientific principles (and no such exist), would in all probability check improvement and progress; and would certainly be very unworthy of the recommendation of a professedly scientific body like the British Association.

I think also that an official assignment of a limit to the load-draught of water would be attended with vexatious interference on the part of local officials most inimical to trade; and I think, with Mr. Laurie, that this is a matter which may be safely left to be settled between the insurers and the insured. It is difficult to conceive any mode of determining legally this limit, which cannot be assigned on any scientific principle that would not operate as a check to the progress of science in the art of shipbuilding, which must be free if it is to flourish with vigour.

On the fifth question I am now prepared to state my opinion, that the present law makes too great a difference between steamers and sailing ships. For the very same reason that a fractional part only of the contents of a sailing ship is taken as the registered tonnage, which in the first instance was undoubtedly to allow ample room for the crew and all the necessary stores and equipment of the vessel, I think that the excepting from the tonnage the space actually occupied by the engines, boilers and coals, is equitably fair. The measurement, however, should be limited to the space *actually* occupied by the engines, &c. It would be unfair to include the space in that on which dues are paid. Not only are the first cost and the expenses of working a steam-ship much greater than those of a sailing vessel of the same capability of carrying cargo, but, in consequence of the motive power, the dues of the one are paid three or four times for each payment by the other.

With regard to the sixth question. In the absence of any information from practical shipbuilders, I can see no valid reason for making any distinction whatever, based on the different materials of which ships may be built. A wooden ship and an iron ship built on the same lines, and calculated for the same deep draught, would differ somewhat in capability of carrying cargo, the difference being in favour of the iron ship, which would also pay a somewhat higher rate of dues, having a larger internal capacity. On the whole I believe by registration of internal capacity the assessment is pretty

fairly apportioned between vessels, whatever be the material of which they are composed. Nor can I see more reason for making a discriminative distinction between vessels, based on the different principles of machinery with which they may be fitted.

With regard to the seventh point. Although the term horse-power, and the measure of useful effect which it represents, have not been specifically fixed by law, I apprehend that, in case of a question arising between builder and purchaser, with regard to the term indicated horse-power, the law-courts would have no difficulty in arriving at a definite meaning of this term.

Not only in England, where it originated, but in America, and generally throughout the civilized world, the measure of useful effect, to which the name horse-power is given, viz. 33,000 lbs. raised one foot high per minute, has long been accepted. The confusion which would be introduced by the adoption of any other measure would be much more than equivalent to any advantage which would attend its adoption, this advantage being, at the most, the approximate assimilation of the indicated horse-, as at present developed by engines on the average, to the nominal horse-power. The great name of Watt has given a value and currency to the present measure, which have placed it beyond all rivalry; nor could any new measure hope to come into competition with it.

The object of the proposal to fix the statute power by Act of Parliament, seems to be, to require that the registered power should be a real measure of the power exerted. It appears to me that nothing could be more difficult than to subject this to an effective measurement, depending, as it does, upon so many different qualities. If it be proposed to register the horse-power as indicated, on trials of ships under certain specified circumstances, nothing could well be more delusive, as it would be by no means difficult, according as it suited the interest of the owner or maker, to make this power, so developed, vary within almost any assignable limits, on one side or other, of the power which would be usually exerted. Nothing can be imagined more inquisitorial than to require private individuals to make such trials of their engines—and all merely to serve scientific purposes—which trials, after all, could not be in the least depended on.

The present *nominal* horse-power is useful as giving the dimensions, &c. of the engine, which must form the basis on which contracts are to be made. It is indifferent whether this be retained in its present form, or the several items be given under the name of "Engine Register." I agree with Mr. Napier in thinking an enforced registration of engine-power needless. I cannot see what the public have to do with it. It is the business of the customer to enter into such a contract with the engine-maker, as to secure his obtaining the article he wants. The terms of a contract are of course open to arrangement between the parties interested; and if in addition to the dimensions, &c. of the engine, the contract includes the stipulation that on a trial trip, under certain specified conditions, the engine shall work up to some defined limit of indicated horse-power, I apprehend that, in case of litigation, a jury would experience no difficulty arising from indefiniteness in the term *Indicated Horse-power*. There never has been more than one measure of this important element, and there seems no necessity of calling in the aid of Parliament to fix it. I apprehend that no practical difficulty has been felt on this score.

With regard to the eighth query:—1st, I see no comparison whatever between the calculations for the 'Nautical Almanac' and the calculations for ships. Astronomical science embraces a wide field; and many of the acutest minds in Europe are employed on it. In the vast variety of methods in use

in practical astronomy, it is to be expected that improvements should be continually made; and it is of course advisable that the officers charged with the responsibility of bringing out the 'Nautical Almanac' should be able to avail themselves of improved methods. Moreover, the Astronomer Royal, who is always one of the most eminent men of science in this country, and it may also be said in Europe, is the superintendent-in-chief of the 'Nautical Almanac.' The reputation and acknowledged ability of the scientific officers concerned in this case are a sufficient guarantee of the accuracy of the methods they employ.

The rule or rules employed for the calculation of tonnage or displacement are of a very different nature. As a matter of fact, no real improvement has been made in the method, in a scientific point of view, since the days of Newton, the rule called Simpson's or Sterling's having in reality been invented by Newton. The great merits of this rule are, that it is as accurate as any rule for the measurement of a figure not strictly geometric can be, and that it is simple and easy of application. As applied to obtain internal roomage, Stirling's rule requires only measurements to be taken at certain intervals, and these measurements are very easily made. The whole process, after the measurements are made, is simply arithmetical. The accuracy of the measurements can be tested by laying them down to a fixed scale on paper, and passing a curve through them; but this curve is not required for the purpose of making the calculations.

Mr. Peake's method is founded on the very same principle; but, in the points wherein it differs, it is, in my opinion, no improvement. First areas of sections are calculated as usual; then two sets of calculations are afterwards required to complete the operation. The areas of sections are represented on paper by lines set off to a certain scale, and an elaborate system of exhausting the area so formed is employed. This is evidently a far more complex and difficult process than to make simple calculations from ordinates at once. In taking, also, the greatest distances from various base-lines of points in the curved portion, Mr. Peake assumes that he obtains the areas more correctly than Sterling's rule gives them. This is a mere assumption, founded on no known property of the parabola, which is the curve supposed to pass through any three points.

We know that a parabola may be made to fulfil five conditions; if it pass through three points it fulfils three of these—and its having its axis parallel to a fixed line, is equivalent to the fulfilment of the other two. We know also, that a parabola so drawn, subject to the ordinary conditions under which this (Sterling's method) is applied, is palpably, to the eye, coincident with the section of the ship. It is, at all events, impossible to draw a regular curve more nearly coincident with it.

It would be very dangerous, as it would be unnecessary, to leave subordinate agents to exercise their own discretion in the use of methods for calculating tonnage, when a rule so simple and correct as Sterling's is at their command. I conceive, therefore, that no alteration is required, or advisable, in the rule now in force under the Merchant Shipping Act of 1854.

I have the honour to be, Sir, your obedient Servant,

J. Yates, Esq. JOSEPH WOOLLEY.

No. 4.—Mr. JAMES ROBERT NAPIER (*Member of the Committee*).

Glasgow, March 2, 1857.

Reply to Tonnage Committee's Circular of 6th November, 1856, by James R. Napier.

1. The objects of registering shipping I believe are,—1st. For the purpose

of levying such dues as to reimburse the proprietors of docks, harbours, rivers, lighthouses, &c. &c., for the expenses they may have been at in providing such accommodation. 2nd. For the purpose of simplifying the process of transferring the property from one owner to another. 3rd. The shipbuilder and shipowner might wish to know the efficiency of a vessel, but I cannot conceive that any public registration is necessary for this purpose, as the shipbuilder or engineer has all the elements in his possession for finding, what may be called, the scientific efficiency, and the shipowner's cash account will soon show him the mercantile efficiency, by the profits he is making upon his capital; and I do not see that the public have anything to do with the question.

3. The present system of tonnage admeasurement is more minute than is necessary, and of little or no use to the shipbuilder, as his designs, calculations, &c. are based almost exclusively upon the weight of ship and cargo, and seldom upon her internal roomage.

4. I am inclined now to take Mr. Russell's view of this subject, and not to limit the load-draft of water.

5. I have not sufficiently considered this question.

6. I cannot see any reason for making a distinction between vessels built of wood, iron, or of any other material, in their measurement. In the registration, the material may be named; it would be useful to do so.

7. Nominal horse-power is a useless term. It has no relation whatever to the power the machine may be exerting, and is a very round-about and even indefinite way of expressing the size of a steam-engine, or rather of its cylinders. According to the Government ideas of the subject, even where every length of stroke (in paddle-wheel engines) has a different velocity for the piston to travel, the size of cylinders for a given power is quite indefinite. It is useless for the purposes of buying and selling, for the cost of construction does not vary as the nominal horse-power. Instead of nominal horse-power, I would substitute simply the capacity of cylinders, or area of cylinders, × length of stroke. This is positive information, and would be useful in buying and selling, and might be inserted in the register of the vessel. A legal standard of power would remove some confusion which at present exists, and as the elements of such a standard are already recognized, viz. the lb., the foot, and the minute or second, there can be little difficulty in combining them, and calling the unit "foot pounds," or "ft. lbs.," per minute or per second. A horse-power is already known to be 33,000 foot lbs. per minute, and I see no good reason for changing this term.

8. *Sterling's rule is very good*, but all vessels, large and small, ought to be divided into the same number of ordinates, and five ordinates would give a near enough approximation to the capacity of the ship for all the ordinary purposes of trade.

No. 5.—Mr. Charles Atherton (*Member of the Committee*).

General Summary of his Report.

The foregoing matters touching the Merchant Shipping Act of 1854, have been thus generally gone into for the purpose of opening up those points of inquiry which bear especially on the limited duties assigned to this Committee by the British Association, namely, "To inquire into the present methods, and to frame more perfect rules for the measurement and registration of ships and of marine engine-power, in order that a correct and uniform principle of estimating the actual carrying capabilities and working-power of steam-ships may be adopted in their future registration," and the

conclusion at which I arrive on the points thus referred to this Committee are,—that the Merchant Shipping Act of 1854 is an admirably conceived base of legislation, intended to concentrate all the objects for which legislation, in its protection of public interests, can be called upon to take cognizance of shipping affairs; that, so far as the inquiries assigned to this Committee are concerned, and which relate exclusively to Part 2 of the Act, there appears to be no absolute necessity for the cancelling any part of the existing clauses; but it is necessary that the provisions of the Act be extended to meet the following requirements, which are indispensable to the protection and promotion of public interests.

1. The Act of 1854 is defective, in so far that the prescribed registration, though called tonnage, takes no direct cognizance whatever of the tons weight of cargo that will either sink the ship, or that will immerse a ship down to any definite gauge-mark. The consequence is, that a ship chartered for the conveyance of merchandise may be filled with some descriptions of goods without being half-loaded, or sunk with other descriptions of goods without being half-filled. To remedy this deficiency, it is necessary not only that the registration shall give the capacity of a ship for holding cargo, as is done by the present law, but also the capability for carrying weight of cargo as determined by the weight that will sink the ship down to a given gauge-mark, to be fixed upon the stem and stern or amidships of every ship.

2. The Act of 1854 is defective, in so far that it prescribes no regulations whereby the draught of water at which ships actually put to sea may be officially inspected and recorded, with reference to a statute gauge-mark, as above described, to be fixed upon every ship, such record to be received as evidence in the case of questions subsequently arising as to the condition in which ships put to sea; for the want of which record many of the provisions of the Act, evidently intended for the protection of life, become futile for want of proof as to the freeboard with which ships put to sea.

3. It is submitted that the official imposition of a gauge-mark to be fixed on the stem and stern of ships, or amidships, for the purposes above referred to, would, of itself, without any interference whatever on the part of Government officers in the loading of ships, tend greatly to the prevention of overloading, whereby ships are rendered unmanageable and life endangered. The provisions of the Act for the protection of life would then become operative instead of being a dead letter as respects the overloading of ships.

4. The Act of 1854 is deficient, in so far that it does not prescribe the measure of the unit by which the registered engine power of steam-ships is to be determined, nor has any other Act of Parliament prescribed the unit of power by which engine-power may be legally ascertained and designated; nor has engineering practice adopted any specific unit as the measure by which marine engine-power is bought and sold. It is admitted that the working-power of marine engines, as supplied to Government by the most eminent engineers under contract at the nearly uniform price of £50 per nominal horse-power, fluctuates upwards of 100 per cent. with reference to their nominal power, which regulates the cost. Under these circumstances, the registration of engine power, without reference to any legalised statute unit, is an imposition on public credulity.

5. It is submitted that the legalisation of a statute unit of power, and the legislative obligation that the registered power or engine capabilities of steam-ships shall be ascertained and registered with reference to the said statute unit, will be no more of government interference with mercantile and engineering affairs, than is the imposition of the statute lineal foot, the statute

gallon, or the statute ton weight. A legalised statute unit of power is a positive requirement of the age. It is not proposed that there shall be any obligation as to engines being worked up to the full power that they are capable of developing, any more than that ships shall not put to sea without being fully loaded.

6. It is further submitted that the deficiencies of the Act of "1854," in respect of the defective registration above referred to, vitiate the public statistics of the country so far as based on the registration of shipping; for, as shown in the foregoing pages, the ratio between the registered tonnage of a ship, and its capability for safely carrying weight of cargo, depends in great measure on the dimensions or proportions of length, breadth and depth of the ship; so much so, that (as shown) a ship of 2000 tons register may be so proportioned as to have no displacement available for cargo without encroaching on the freeboard necessary to the safety of the ship, whilst another ship may be so proportioned externally and constructed internally as to carry safely the double of her registered tonnage, especially in the case of auxiliary powered steam-ships, which now threaten to supersede sailing ships altogether. Hence the mere registered tonnage of ships is not of itself a statistical criterion of the extent of trade, excepting in so far as respects the carrying power of similarly proportioned and similarly built vessels.

7. Registration under the Act of "1854" does not meet the requirements of commercial operations, as shown by shipping advertisements, which frequently ignore the legalised registration under the Act of "1854," and refer to other designations of tonnage, such as gross tonnage, tons burden, tonnage O.M., tons (without designation), all which terms are made use of irrespective of the register ton, and not one of all these five terms for tonnage expresses or has any constant ratio whatever to the one thing needful, namely, the tons weight of cargo that a ship will carry with reference to any statute gauge mark. Then, again, we see engines advertised as 100 H.P. nominal, but 450 H.P. effective, and neither nominal H.P. nor effective H.P. have any statute signification or definite ratio to each other.

8. The Act of "1854" in respect of its registration deficiencies, is obstructive of the application of science to maritime engineering and architecture, as respects all investigations into the comparative dynamic performances of steam-ships as a means for practically determining the best type of form for the respective purposes or services for which ships may be required. The extent to which this exclusion of science for so important a part of naval engineering and architecture as that of developing the dynamic economy of different types of ships, is adverse to public interests, may be judged of from the fact, that on estimating the comparative dynamic capabilities of ships of given size, and required to steam at a given speed, but of different types of form, by any recognised law of scientific comparison, a vast difference of dynamic merit is found to be prevalent. The great majority of ships are found to be of a low order of dynamic merit, below what has been found to be practically realisable; so much so, that the average of the generality of shipping requires probably 25 per cent. more power to attain a given speed than is required (*cæteris paribus*) by vessels of the superior type, which is occasionally produced; and when it is considered that the trade and navigation returns for "1856" show that the foreign import and export trade of Great Britain, as indicated by the registered tonnage of shipping, amounts to 18 millions of tons per annum, whilst the home trade amounts to 26 millions, being a total of 44 millions of tons per annum, sea-borne trade (that is, if the weight-carrying capability of ships be on the average equal to the register tonnage), and as the cost of all merchandise to the consumer,

such as corn and cotton, depends considerably on the cost of transport, it must be admitted that the registration of tonnage and engine power, though required only for the exclusive purpose of rendering science available for improving the dynamic performances of steam-ships, is, of itself, a consideration which demands the interference of the legislature as the guardian of public interests in all public affairs.

In conclusion, therefore, it is submitted that the defective condition of our shipping registration under the Act of "1854," is such as demands the consideration of parliament with a view to the extension of the Act to meet the following requirements:—

1. That a statute gauge-mark shall be affixed on each side, amidships of every ship, for indicating the statute freeboard, the exact position of said mark to be determined by a rule based on the length, breadth and depth of the ship taken in such proportions as the legislature shall determine, and corresponding marks shall be fixed on the stem and stern at such position in line with the midship mark as the approved water-line trim of the vessel shall indicate, and the dimensions of length, breadth and depth by which the position of the midship mark is determined shall be registered.

2. That in addition to the present registration of tonnage, based on internal measurement, the registration shall include the displacement of the vessel when light ready to receive cargo equipped in all respects ready for sea, but not including coals and other consumable stores, also the displacement when immersed down to the statute gauge-marks before referred to, and the total displacement measuring up to the deck; these displacements taken in cubic feet, to be rated at $35\frac{1}{2}$ cubic feet to the ton weight, and the difference between the light displacement, and the statute gauge-mark displacement, to constitute the registered weight-tonnage of the ship.

3. That the draught at which ships actually put to sea shall be inspected and recorded with reference to the statute gauge-mark on the stem and stern of the ship.

4. That a standard measure of power be determined and legalised as the statute unit, to which the registration of the engine power of steam-ships shall have reference; the registered power shall be that which engines and boilers shall, for the time being, be capable of continuously exerting, the same being ascertained by means of the indicator, as usual in the trial of steamers, and calculated by the statute unit.

CHARLES ATHERTON.

Woolwich Dockyard, 3rd March, 1857.

No. 6.—Mr. ANDREW HENDERSON (*Member of the Committee*).

General Summary of his Report.

The British Association having appointed a Committee "to inquire into the defects of the present methods, and to frame more perfect rules for the measurement and registration of ships and marine engine power, in order that a correct and uniform principle may be adopted in their future registration," the following review of the opinions and information is submitted, premising that the members of the Committee, being unanimous in opinion that the removal of all fiscal dues levied on tonnage would be the best solution of all the difficulties connected with the tonnage question. Although not included in the above, it was considered so important, that the writer was deputed by the Committee to seek information on the subject.

The result of this inquiry shows that, although the original object of *register tonnage* may have been the taxation of the cargoes of ships, it has

long since ceased to be used as a basis of taxation, inasmuch as all fiscal dues or duties are levied by the Custom-house on the cargoes imported and exported.

The only dues or rates levied on tonnage are for harbour and dock accommodation and light dues, for maintenance of lights on the coast; the former being mostly paid to local trusts or dock companies, while the light dues, although levied by the Custom-house, are paid to the Trinity-house for the maintenance of the lights; so that these dues cannot, in point of fact, be any longer considered as fiscal or government.

Many of the light-houses, previous to 1835, were private property, till purchased by the Trinity-house Corporation, who thereby incurred a debt of £1,200,000. The shipowners have paid off both principal and interest. The light dues now charged on tonnage amounts to £313,208, and the cost of maintenance amounts to £214,700, the surplus revenue from light dues, £98,508, being received by the Board of Trade for the Mercantile Marine Fund.

The coasts of France and America are lighted by their respective governments without charge on shipping. Both equity and policy dictate the expediency of relieving the shipowners of this country from all tonnage dues for lights, and transferring the charge to the cargoes and passengers carried by ships, or to the Consolidated Fund.

A bill in parliament proposes to abolish all passing tolls and town dues levied on shipping, the latter at Liverpool amounting to £125,000 a-year, being raised by a small rate levied on all cargoes imported or exported on the Mersey. A similar rate on cargo levied at all other ports would provide the £250,000 annually required for maintaining the lights, buoys and beacons, and for the conservancy of the ports and rivers on our coasts. The substitution of light dues levied on cargo and passengers for the present tonnage dues levied on shipping, would entail no additional labour on the Custom-house officers, as they must necessarily keep a record of all goods imported and exported at each port. This is a more legitimate occupation than the measurement of ships, which is stated to be "an extraneous duty thrown upon their officers," in a report from the Commissioners of Customs recently published.

Both economy and efficiency would be effected by the transfer of the duty of measuring ships from the Custom-house officers and department, to the shipwright and engine surveyors, now employed by the Board of Trade for all ships carrying passengers, whose certificate of survey would furnish the Custom-house with the dimensions, register, and gross tonnage, and other particulars required for the various forms of register and transfer of vessels; these also forming the record for compiling the statistics of the shipping of the country, which comprises the only remaining usefulness of tonnage registration for statistical purposes at the Custom-house, there being no longer any fiscal dues or Government duties levied on the tonnage of shipping, notwithstanding which, up to the present time, the Board of Trade and Government have only considered the measurement of tonnage and registration in a purely fiscal point of view.

The reasons for these conclusions will be found in the facts of the working of the present system, detailed in the foregoing paper, in which it was found necessary to refer to the proceedings of former committees, and the different principles of measurement in use.

In 1835 an Act was passed adopting the principle of internal measurement for register tonnage.

In 1849 the subject was again investigated by a committee, consisting of

Lord J. Hay and a body of shipowners, who reported that "the equitable basis on which charges for dock, light, harbour, and other dues, is that of the entire cubic contents of a vessel measured externally." A bill, based on this recommendation, was brought in, computing the tonnage by means of diagrams of section, and curves of areas, with a scale of displacement.

This bill was opposed by the owners of timber ships and the builders of iron vessels, and from this and political causes was deferred.

At that time I proposed that the principle of the bill of 1850, and of the plan recommended by Mr. Moorsom for internal measurement, should be embodied in one bill, and the mean of the two measurements be taken as the basis for register tonnage; and before the bill was actually passed, I submitted that this could still be accomplished by combining the Rule No. 1 of the bill of 1850 as well as Rule No. 2, which already forms part of the bill, by an alteration of the clauses 20, 21, 22, of the present act.

Register tonnage is necessary for statistical purposes, but should approximate the old builder's tonnage, in which the statistics of shipping have, from the earliest times, been kept, and which more nearly assimilates that of other nations. There are, however, objects to be attained by a more comprehensive system of tonnage registration, viz. the safety and efficiency of the ships, their mercantile capabilities, and to supply scientific data for facilitating a comparison of the various types of ships, including a record of their burthen in weight or displacement, capacity, strength of material and steam-power. The practicability of obtaining this record is exemplified by the annexed table of the dimensions and proportions of ships and engines and comparative analysis of their capacity, resistance, and the result of test-trials and performance at sea; the particulars recorded of many affording data for estimating the comparative dynamic merits of ships by the co-efficient of their displacement or index number. The additional measurement and data required are shown in the table. (Appendix A.)

With this view it is proposed to substitute for the forms now sent to the Custom-house, the record, on the present builder's "certificate, of all particulars of dimensions, old tonnage and measurement by new rule, mentioned in the accompanying form, giving the builder's construction, load, draft, displacement, and area of midship section, as well as the launching draught, and estimated weight of hull and fittings as the light water-line, from which a scale of displacement and area of midship section may be formed at any draught of water." (Vide Appendix B.)

These particulars relating to the external bulk and internal space, with the draught, displacement, and area, would not only give the internal capacity, but also the capability for carrying weight of cargo, as well as the data forming a scale for displacement and area of midship section at any draught of water, whence may be deduced the relative efficiency of different vessels.

I consider the present plan of taking and recording the internal measurement, and the mode of computation to be practically inefficient for obtaining a correct mensuration of vessels, and that the formula and mode of calculating are extremely liable to error, without the means of testing their correctness, as was suggested by the Tonnage Committee of 1849.

The Act of 1854, though nominally adopting the same scientific rule, in effect abandoned the most important part, viz. the use of the diagram and curves of areas.

By using paper ruled to a scale in the formation of the diagram, the computation is rendered both easy and correct, and a record of these measurements, &c. in the certificate of the surveyor would furnish the owner or

government with the means of ascertaining the weight of cargo carried or the capacity for light goods.

All measurements, however made, ought to be attested by the builder or owner, &c. and recorded on the certificate.

The correctness of Sterling's rule is entirely based on the assumption that the sections should be measured at exactly equal distances, but experience proves that in practice it is almost impossible to obtain these measurements at the exact intervals required.

It is, however, of comparatively little importance by what method a vessel is measured, provided means are at the same time used to check the calculations, and the most simple and practical mode of accomplishing this is by the method so long used by Mr. James Peake, viz. by a system of vertical sections and curves of areas, measured by a series of triangles. Annexed is a comparison of four modes of measurement. (Appendix C.)

The black lines on the right side show the plan as recommended by the Tonnage Commission of 1849, and the measurement proposed in Bill of 1850.

The triangular lines on the extreme right represent Mr. Peake's method for displacement to load-line.

The dotted lines on the left represent Mr. Moorsom's mode, adopted in the present act, as shown in formula No. 1, p. 30, in substitution of that recommended by the Tonnage Commission, of which he was secretary.

The diagonal lines on the left represent M. Norman's on the French plan, useful in correcting other measurements, or if built true to design.

For statistical purposes, owing to the great decrease, as above shown, of from 8 to 10 per cent. in the Register Tonnage, below the average of the same vessel under the late law, this must impair the object of statistical returns, and injure the harbours, piers, and docks, maintained for shipping, while it reduces the charges and light dues only, and is consequently very popular with shipowners.

Two years' experience in the practical working of the present tonnage measurement and registration system, has proved deficient and non-effective for the attainment of most of the objects of public utility sought for.

The advantages of internal over external measurement have been stated to be, that inasmuch as the greatest number of cargoes carried by our merchant shipping consist of stowage goods, not dead weight, equal to at least three-fourths of the whole, and as ships' sides and bottoms are of various scantlings and thickness, and are constructed of materials of different weight, external measurement would give advantage to some ships over others, of 15 to 20 per cent.

This is, however, not the fact, as an examination into the trade returns of 1850 exhibits the following results of the trade of the United Kingdom, amounting to 10,760,297 tons of imports and exports; of which 7,483,214 tons, or $69\frac{1}{2}$ per cent. were of heavy goods (coal, metal, grain, and sugar), and 3,277,083 or $30\frac{1}{2}$ per cent. of light goods, of which a timber-built ship will carry 10 per cent. less than iron vessels.

With respect to the working of the Act of 1854, it appears that in September 1855, a great many vessels were remeasured under the new act, it being found that the Rule No. 1 for internal measurement reduces the register tonnage from 5 to 10 per cent., an important saving of dock and light dues to coasting steamers, besides some increase in the deduction for engine-room; while by Rule No. 2, for external girthing, the gross tonnage was increased 5 per cent. on the late measurement, and ranged from 5 to 15 per cent. more than by Rule No. 1.

The war caused a great demand for screw steamers hired by the ton, and induced the numerous remeasurements under the new act; thus the anomalies of our tonnage laws are exemplified by there being three or four different measurements in use, all nearly equally indefinite as to the real bulk efficiency or tonnage capacity of vessels transferred.

With respect to the fixing the load limit;—at present we can obtain from the builder his construction load line and launching draught, and if in addition we obtain the draught of water, the scale of displacement, and area of midship section, we have sufficient data for assigning a proper limit of loading, and marking it on the register as in Appendix B.

Should the builder assign a load draft and displacement, such as nautical science may not justify, and as the safety limit must also depend much on the proportions and form of the vessel, the load draught of water and height of freeboard may be ascertained as follows:—For example, take one-twentieth of the length, one-fifth of the breadth, one-fifth of the depth, and divide by three—the result will be the safety freeboard measured from the deck or gunwale and the mean draft of load water, which should be mentioned in the register and never exceeded.

In conclusion, all that is requisite is, to alter the three clauses given in the present act of 1854, as it embodies the principles recommended by the Tonnage Committee of 1849 (and contained in the Bill of 1850), together with all the advantages derived from internal measurement, as given in the present act; and bases the register tonnage on the mean of the external bulk and internal space, thereby affording internal capacity and a displacement measurement, from which the weight of cargo carried could be ascertained.

Alterations in the Clauses of the Merchant Shipping Act, 1854, *appertaining to the Measurement of Ships for Tonnage, proposed by A. Henderson* *.

Clause 20. Throughout the following rules the tonnage deck shall be taken to the upper deck in ships which have less than three decks, and to be the second deck from below in all other ships; and in carrying such rules into effect all fractions of feet shall be expressed in decimals. "It being considered that the equitable basis on which charges for dock, light, harbour, and other dues should be made, is that of the entire cubical contents or external bulk to the medium height of the tonnage deck, together with the internal space or capacity under the tonnage deck (within the ceiling planking, exclusive of lower deck beams and fixtures of hull); the mean of the two being taken as the basis of registered tonnage. These quantities to be expressed in cubic feet and decimals on the register and certificate. The difference between the external bulk and internal space to be considered the cubical contents of the hull of the vessel; the per centage or ratio the cubic contents of the hull bear to that of the internal capacity, and of that quantity to the bulk, giving a fair criterion of the relative capacity of timber and iron ships for light goods and passengers."

Clause 21. The tonnage of every ship to be registered, with the exceptions mentioned in the next section, shall, previously to her being registered, be ascertained by the following rules hereinafter called Rule I. "for External Measurement and Internal Measurement"; and the tonnage of every ship to which such rule can be applied, whether she is about to be registered or not, shall be ascertained by the same rule.

* The additions shown in italics or inverted commas.

APPENDIX A.

TABULAR COMPARISON, THE OLD, THE PRESENT, AND PROPOSED MEASUREMENT FOR TONNAGE, AND ANALYSIS OF SHIPS AND STEAMERS, THEIR PROPORTIONS DISPLACEMENT WEIGHT, AND RESISTANCE, ENGINES AND STEAM POWER, AND RESULTS OF SPEED REALIZED

The want of a uniform mode of measurement occasions [illegible] Length and Breadth at the Load water line to be marked [illegible] also marked W, if at the water line: Ex, if extreme, and M, if the moulded breadth. The fairest measurement of depth is from medium height upper deck [illegible] of the keel; if the deck is not flush, [illegible] be increased [illegible] scale or curve to be formed of Tonnage [illegible] Displacement, Area of Mid Section, and [illegible] proportion as at a being the working power. A record of its ratio to the nominal horse power forming a test of the capabilities of the engine. That of the vessel being the speed realised in geographical miles or knots. The best criterion of efficiency being deduced from these quantities by the formula for the co-efficient of Displacement, and of Area of Mid Section, these being based on the type H.M.S. *Rattler*, whose index number and dynamic duty was 215. *Note*.—The average speed realised by the contract steamers is calculated from returns made by the Post Office and Admiralty Report on Steam Communication with India, p. 693, Session 1[illegible]. These average speeds and ratio of indicated horse power with the mid voyage Draft and Displacement, the co-efficient may be obtained for the year's service. *Note*.—The italics refer to 9 of the 46 vessels, the particulars of which were furnished to the Committee by the Peninsular and Oriental Steam Company.

Register of Steamers (cols. 1–4); Internal and external (cols. 5–8); [illegible] only, the depth being assumed to be half the breadth (col. 9).

Dimensions and Proportions

Vessels Name, Builder, and Date (10)	9	11		12		13		14	15
Great Western ... Patterson ... 1838		207	3 W	35	2		...	6 86	
Acadia, Halifax Line ... Wood ... 1840		207	6¼	34	2 E	22	2 H	6 07	·64
Comprehensive, designed by ... A. Henderson, 183[illegible]		240		42	..	34		6 71	·80
Precursor } Calcutta Line { Napier ... 1842		226	W	37	W	24	H	6 08	·65
Haddington } Calcutta Line { Bailey ... 1846		219	6 W	35	W	31	6 W	6 27	·90
Bentinck } Calcutta Line { Wilson ... 184[illegible]		217		36				6 02	
Ajdaha ... Indian Navy .. Ritherdon ... 1846		P 220	Ex.	37	E	23	...	6 94	·63
Locust, H.M. str. Malta line ... Symonds ... 1840		117	6 W	22	5 W	13	8 W	5·14	·66
Merlin ditto ditto Symonds ... 1838		171	6 W	33	W	17	8 W	6 20	·53
India, East Indies ... Scott ... 1840		P 183	...	28	10	26	W	6 55	·60
Alma		288	1	37.7				7.64	
Madras		232		31.6				7.34	
Ava		267	5	35 2				7.60	
Singapore		236	3	29.4				8 09	
Achilles ... China Line ... 1846		205	9	27	...	...	..	7·59	...
Pekin (Iron) ... ditto ... 1846		214	7	29	7	...	..	7 25	...
Malta ... ditto ... 1846		205	9	33	6	...	...	6 14	...
Hindostan ... Calcutta Line ... 1842		217	6	35	8	...	...	6 07	...
Oriental ... ditto ... Wilson altered 1848		220	...	33	5	...	..	6 58	...
Hibernia, Holyhead Mail ... Vernon ... 1848		190	P	26	9 E	13	9	7·10	·61
Oronoco, West Indies ... Pilcher ... 1851		267	4 W	41	10 W	33	8	6 38	·70
[illegible] ... Napier & Son ... 1855		360	P	45	W	31	6	8·	·71
[illegible]		[illegible]		42				7 22	
[illegible]		[illegible]		[illegible]				[illegible]	
[illegible]		[illegible]		[illegible]				[illegible]	
Alhambra		209	3	27.1				7.76	
Cadiz		226	4	28 4				7.97	
Australasian ... J. & G. Thompson		324		42	6	31	6	7·66	
Arctic American Mail Steamer		282	...	46	...	32	..	6 27	·72
Susquehanna ditto		257	...	46	...	26	6	6 71	·59
Great Britain, Screw Steamer ... Patterson ... 1844		289	...	50	...	32	...	6·78	...
Himalaya ditto ... 1853		341	...	46	...	32	6	7 41	
Bengal ditto ... Tod & Macgregor ... 1853		300	6	39	6	30	0	7 3	·79
Argo, Gen. Screw Steam Co., Mare & Co. ... 1853		246		39	6			6 20	
Victoria, Australian, do. J. Scott Russell ... 1852		261	4	38	1	27	...	6 85	·71
Proposed by R. Roberts, Manchester ... Iron		400	...	60	...	35	...	6·66	·68
Do. I. K. Brunel, East S.N.Co. building by J.S.Russell		680	...	83	...	54	..	8·19	·79
Great Republic American Sailing Clipper ... Timber	4,555	3[illegible]5	...	50	...	39	...	6 45	·75
Tayleur English ditto ... Iron	1,631	225	...	39	...	28	...	5 77	·72
Mary Stewart ... Samuda ... 1857	313½	136	P	23		15	8	5.92	·69
Screw Steam Packet, constructed of [illegible]									
Screw Steam Packet, constructed of iron and wood.		P 133	...	24	..	15	2	5 54	·63
Screw Steam Packet, constructed of iron.									
Kelpie, opium clipper, constructed of wood.		P 108	...	27	4	17	5	3 94	·64
Monarch.	56								
Essex.									
Euphrates.									

Draft Displacement and Area; Weights

Vessel	16	17	18	19	20	21	22	23	24	25
	Builders or Construction: Mean Draft of Water	Displacement	Area of Midship Section	Ratio	Launching or Light: Draught of Water	Displacement		Weight of Hull	Engines, Boilers & Water	Provisions
Great Western	17 0	2,393	460	4 71				926	400	540
Acadia	17 0	2,186	482	4 6				765	420	567
Comprehensive	19 0	3,335	608	...				1,300		
Precursor	17 0	2,505	...	...	12 6	1,672		925	620	703
Haddington	17 0	2,300	525	...				1,220	360	..
Ajdaha	..	...	...	...				...	...	...
Locust	9 3	416	182	2 28				186	100	58
Merlin	11 4	1,073	296	3 62				393	320	170
India	15 0	1,260	350	3 32				560	300	105
Achilles	...	...	...	...				...	...	...
Pekin	...	...	...	...				...	...	...
Malta	...	...	...	...				...	...	...
Hindostan	..	...	...	...				..	...	...
Oriental	...	...	...	...				...	...	...
Hibernia	11 0	950	256	...				380	325	...
Oronoco	19 8	3,798	662	...				1,490	700	1,000
[illegible] (Napier & Son, 1855)	22 0	5,444	835	6 39						
Australasian	23 0	4,760			14 6	2,400				
Arctic	20 0	...						1,525		
Susquehanna	..	...			19 6	3,824		1,470	726	
Great Britain	17·0	3,280	690		9 6	1,460		..	...	..
Himalaya	...	...			...	...		...	...	...
Bengal					10	1,408		...	...	...
Victoria	18 5	3,000	595							
Proposed by R. Roberts	..	...	816		10·2	4,730				
Tayleur	18 6	26·50	705		10·6	1,179				
Mary Stewart	11.2									
Screw Steam Packet, iron and wood	...	...	208		6 12	159		158 / 148	...	...
Kelpie	...	..			6 7	114				

Elements of Resistance

Vessel	26	27	28	29	30	
	Area of Longitudinal Section	Area of Load W. L.	Immersed Surface	Angle of Rise of Floor	Water Line with [illegible]	
Great Western	..	..	..	5°	66°	39°
Acadia	...	...	...	...	..	30°
Comprehensive	3,796	6,877	11,013	5¼	44°	31°
Precursor	3,665	6,446	11,230	4°	41°	
Haddington	...	...	...	5°	42°	28°
Locust	1,117	2,205	5,353	5°	47°	27°
Merlin	1,976	4,768	7,405	2° 30	49°	32°
India	...	...	..	4°	40°	30°
Achilles	...	...	...	..	...	...
Pekin	...	...	...	..	...	...
Malta	...	...	...	..	...	...
Hindostan	..	...	...	..	...	...
Oriental	...	...	...	...	...	...
Hibernia	..	3,791	...			
Oronoco		9,165		10° 6°	35° 27°	25° 1[illegible]
Arctic			9,369			
Great Britain	4,600	...	..	2°	22	19°
Himalaya	...			26°		
Bengal	6,162	9,264	16,866	13°		
Proposed by R. Roberts	20,686	20,444	31,597	0°	46°	16°
Tayleur				10°	36°	25°
Screw Steam Packet, iron and wood	1,623	2,320	4,410	18	29	23

Engines Propellers

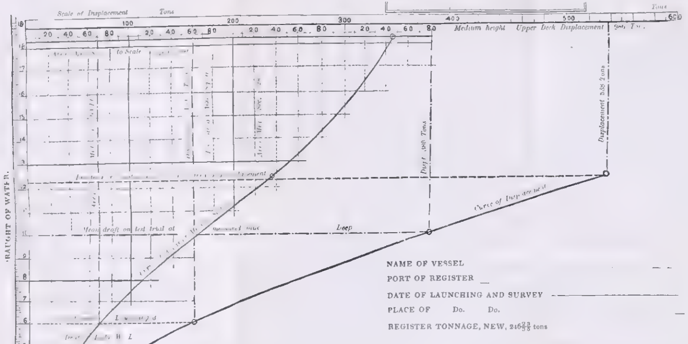
Vessel	31	32	33	34	35	36	37
	Description of Engines	Diameter of Cylinder	Length of Stroke	Working Pressure of Steam	Diameter of Propeller	Pitch of Propeller	Nominal Horse Power
Great Western	B	...	...	..	...	...	400
Acadia	B	..	...	..	...	...	420
Comprehensive	...	..	..	..	33 6	...	..
Precursor	B	...	...	..	...	...	520
Haddington	..	78	80	10	30 0	27 5	450
Bentinck	B	71	81	7	20 0		520
Ajdaha	..	...	...	...	...	...	600
Locust	B	40	42	...	15 5	11 4	100
Merlin	B	64	72	..	24 6	18 0	300
India	B	...	...	...	...	...	300
Alma	Os.	78	60	16	S 16.3	21@24	450
Madras	B	63	60		S 11	18@20	275
Ava	T	70	48	17	S 11	19 6	320
Singapore	D. Os.	77	78	13	P 28		470
Achilles	...	...	...	...	...	...	400
Pekin	...	...	...	...	...	...	400
Malta	...	...	...	...	...	...	...
Hindostan	B	78	96	8	32 0	...	...
Oriental	..	..	...	..	...	...	410
Hibernia	...	73	74	...	27 7	28 8	370
Oronoco	2 C		108		40 0		800
[illegible]	F grd	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	450
[illegible]	D grd	[illegible]	[illegible]		[illegible]	[illegible]	630
[illegible]	D grd	71	45	...	[illegible]	[illegible]	450
Alhambra	D 2 p r	50¼	36		S 11	14	140
Cadiz	D grd.	56	48		S 12	16@19	220
Australasian		90	42	20	S 19		534
Himalaya	D	34½	44	14	S 18	28	700
Bengal	B	80	60	12	S 14 3	18@22	465
Victoria							460
Mary Stewart	Os.	52	42	9	P 16	A 13½	172

Test Trial or Mid Passage; Rates; Name of Vessel

Vessel	38	39	40	41	42	43	44	45	46	47	48	49	50	51
Great Western									5 98	...	3 1	8 82	211·2	Great Western.
Acadia				...	..				6·20	...	3·75	8 50	204·	Acadia.
Comprehensive				...	..					...	..			Comprehensive
Precursor				...	9 72				1 82	316·7	2 84	7·733	186·7	Precursor ..... 38,000 Calcutta & Suez
Haddington				..	..				5·11	...	2 90	8 154	195·7	Haddington ... 111,240 ditto
Bentinck											3 79	[illegible]	191 [illegible]	Bentinck ... [illegible] ditto
Ajdaha				...					...	...	2 88	8·568	205 5	Ajdaha [illegible]
Locust					8 41				4·16	...	2 82	...	...	Locust.
Merlin				.	11·6				8 58	...	2 96			Merlin
India				...					4 2	...	2·56	7·73	185·[illegible]	India ..... Calcutta & Suez
Alma	19	2640	541½	1416	12 13	247	668	·21						
Madras	14	1381	340	764	11.18	229	629	[illegible]						
Ava	16.6	2023	102	1056	12 44	289	731	3 3						
Singapore	12 4	1569	334	1124	11 93	203	505	2,38						
Achilles				..	...				...	...	2 18	8 242	197 7	Achilles ..... 49,600 ditto
Pekin				...	...				...	...	2 83	7·733	185·5	Pekin ..... 48,400 ditto
Malta				..	...				...	...	...	7·402	177·0	Malta ..... 26,800 Ceylon & China
Hindostan				...	...				...	...	...	9 195	220 6	Hindostan ... 53,320 Calcutta & Suez
Oriental				...	..				...	..	46	8 468	231·9	Oriental ..... 61,680 ditto
Hibernia				..	13·				2 59	...	1·78	...	...	Hibernia.
Oronoco														Oronoco.
[illegible]	18 1	2·31	548	1373	12 63	245	803	3 05						
[illegible]	17 6		517		[illegible]									
[illegible]	18.6	2436	627	1415	12 66	258	753	3.11						
Alhambra	11 6	840	267½	454	11.66	230	693	3.24						
Cadiz	12 4	908	262	460	11.69	322	906	2 01						
Australasian	21.6	4360			13 [illegible]									
Arctic														Arctic.
Susquehanna														Susquehannah.
Great Britain														Great Britain.
Himalaya	16 11½	3260	556	2050	13.9	275	700	2.92						Himalaya.
Bengal	15.6		478	1091	11 12			2 93						Bengal.
Argo														Argo.
Victoria					[illegible]						1.			Victoria.
Proposed by R. Roberts														Proposed R. Roberts.
Do. I. K. Brunel														Half built on Thames, 1855.
Great Republic														Great Republic.
Tayleur														Tayleur.
Mary Stewart	8 9	600	200	406	9.53	120	348	2.36			[illegible]			
Screw Steam Packet, wood														Screw Steam Packet, wood.
Screw Steam Packet, iron and wood														Screw Steam Packet, iron and wood.
Screw Steam Packet, iron														Screw Steam Packet, iron.
Kelpie														Kelpie.
Monarch														Monarch.
Essex														Essex.
Euphrates														Euphrates.

The old or builders' Tonnage in 9th column, deduced from the length and breadth, the depth being assumed to be half the breadth, has been the statistical tonnage of shipping till 1835. Cols. 1 to 4 contain the internal measurements and register tonnage of Act 1836 and 1845, as also the Act of 1854, no other particulars being furnished in the register.
The 5th column shows the cubic contents of each vessel measured externally by means of a curve of areas from five transverse sections to the medium height of the upper d[illegible] of timber and those of iron.
The 6th column contains the internal space and feet, which, divided by 100, gives the tonnage by Act 1854, adopted for tonnage, on the assumption that light cargoes exceed those of dead weight. It appearing from trade reports, that heavy or dead weight cargoes greatly exceed the light goods cargo shipped; that numerous vessels are now constructed of iron as well as timber, and that the measurements can be taken either externally or internally for both.
In 7th column is shewn the mean of the external bulk and internal space wh[illegible] proposed to be adopted as [illegible] basis of tonnage for light, harbour and other dues, and as between ship and ship, taking [illegible]
This could be effected by a [illegible]
Note.—[illegible]

Appendix B.—Proposed Scale of Tonnage and Area of M. Section, to be recorded on the Certificate of Register and Forms of Transfer.



NAME OF VESSEL

PORT OF REGISTER

DATE OF LAUNCHING AND SURVEY

PLACE OF Do. Do.

REGISTER TONNAGE, NEW, $216\frac{23}{35}$ tons

	Feet length.
Length from fore part of stem under the bowsprit, to after side of head of stern post .	136
Main breadth to outside of plank	24
Depth of hold from tonnage deck to ceiling at midships	14
Tonnage, old or builders' measurement (ratio of bulk to ton 97½ cubic feet)	$351\frac{6}{94}$
Length of weather deck at its medium height	138·9
Depth from deck to lower edge of rabbit in keel	17·2
External bulk to medium height of weather deck (displacement for scale 986 tons	31612 cubic feet
Internal space to under side of ditto ex lower deck ..	24010, ratio to bulk 665.
Cubical contents of materials of hull, including lower deck	11602, ratio to space [illegible]
Mean of bulk and space, tons 825, or cubic feet ..	28811 ÷ 35 × 30 [illegible] 16·94 tons register.

Length between perpendiculars at rabbits in stem and stern post, or low water-line, 133 feet... } ratio of { Length to breadth, 5·5.
Breadth at Do. Do. Do. Do. 24 „ ... } { Depth to breadth, ·67.

Estimated weight of hull, masts, anchors and fittings, 159 tons. Ditto displacement, light, water-line, draft, 6 feet.
Constructor's load-line, or test trial, displacement, 538 tons. Load water-line, draft, 12·3 feet.

Note.—The above to be added to the particulars in the 15 form of Act 1854 A to O for Survey, Ownership, Register, Sale, Mortgage, &c.

Appendix C.—Comparison of four modes of measurement for Tonnage, the construction of diagrams of sections on paper ruled to a scale on which to form curves of areas and scale of displacement, as proposed by Andrew Henderson, Esq., 1857.

The internal measurement adopted in the Shipping Act of 1854, is now proposed to combine with the external bulk, taking the mean as the basis of Register Tonnage.

These external measurements are, according to Rule No. 1 of the Tonnage Bill of 1850, adopting the use of curves of areas and scale of displacement now proposed, to be added to the Act of 1854.

.... Represents

Mr. MOORSOM'S MEASUREMENTS.

(Internal.)

As adopted in the Shipping Act of 1854, with Formula No. 1, for which it is proposed to substitute the following record of measurements and formation of diagram of section.

Areas.	Breadths.		Multiple.	Products.	
No.	Ft.	In.		Ft.	In.
1 ...	...	8	1	..	8
2 ...	8	9	4	35	6
3 ...	10	2	2	20	4
4 ...	10	4	4	41	6
5 ...	10	2	1	10	2
				108	6
⅓ com. interval × .				1	2
				2172	
				1086	

Internal area ½ section ,129·32

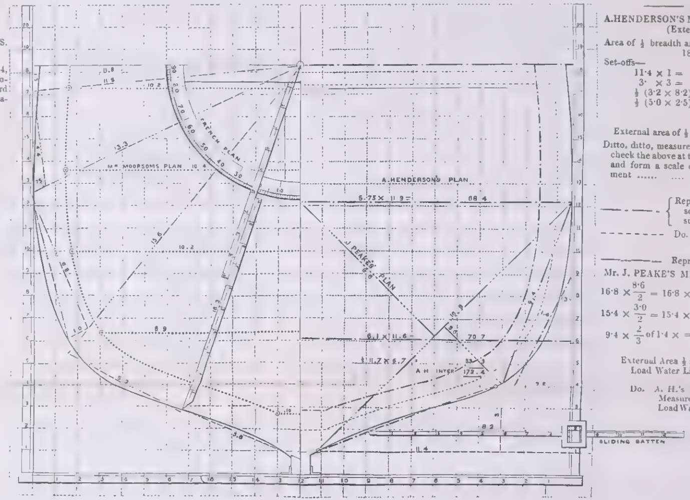
- - - - - Represents

M. NORMAN'S FRENCH PLAN MEASUREMENTS.

(External.)

½ 16·3 × 5·8 = 47·27
½ 15·6 × 5·3 = 41·34
½ 13·3 × 6·8 45 22
½ 11·8 × 4·4 25 96
½ 11·8 × 1·3 · 7·50
½ 6·7 × 1·0 = 3 35
½ 4·3 × ·75 - 1 61

External area ½ section 172·25



——— Represents

A.HENDERSON'S MEASUREMENTS.

(External.)

Area of ½ breadth and height, 18·0 × 11·9 } 214·2

Set-offs—

11·4 × 1 =	11·4	
3· × 3 =	9·	
½ (3·2 × 8·2) =	16·1	
½ (5·0 × 2·5) =	5·7	
		42·2
External area of ½ section		172·0
Ditto, ditto, measured inside, to check the above at three points, and form a scale of displacement		172·4

— - — - { Represents A. Henderson's internal measurements.

- - - - - - - - Do. iron ships, Do. Do

——-——-—— Represents

Mr. J. PEAKE'S MEASUREMENTS.

$16·8 \times \frac{8·6}{2} = 16·8 \times 4·3 =$ 72 24

$15·4 \times \frac{3·0}{2} = 15·4 \times 1·5 =$ 23·10

$9·4 \times \frac{2}{3}$ of $1·4 \times = 9·4 \times \frac{2·8}{3} = 8·77$

External Area ½ section to Load Water Line ...... } 104·11

Do. A. H.'s External Measurement to Load Water Line } 104

Rule I.—1. Measure the length of the ship in a straight line along the upper side of the tonnage deck from the inside of the inner plank (average thickness), at the side of the stem to the inside of the midship stern timber or plank there, as the case may be (average thickness), deducting from this length what is due to the rake of the bow in the thickness of the deck and what is due to the rake of the stern timber in the thickness of the deck, and also what is due to the rake of the stern timber in one-third of the round of the beam; to be termed the length for tonnage. "The height for tonnage to be taken from a base line at the underside of the false keel to the medium height of the tonnage deck. The breadth for tonnage to be the extreme breadth, exclusive of doubling. Divide the length so taken into the following number of vertical sections required for the measurement of transverse areas at nearly equal distant divisional points."

Table.

Class 1. Ships of which the tonnage deck is 50 feet long or under, into four parts, for the measurement of "three transverse areas at the main breadth section, and other divisional points of the length."

Class 2. Ships of which the tonnage deck is above 50 feet, and not exceeding 120 feet, "into sections for measuring five transverse areas."

Class 3. Ships of which the tonnage deck is above 120 feet, not exceeding 180 feet, "into sections for measuring seven transverse areas."

Class 4. Ships of which the tonnage deck is above 180 feet, not exceeding 225 feet, "into sections for nine transverse areas."

Class 5. Ships of which the tonnage deck is, according to the above measurement, above 225 feet, into 12 sections, for measuring eleven transverse areas at the point of division. "The length of the tonnage deck from stem to stern, on a scale of quarter-inch to a foot as a base line, from which the transverse areas being set off on a scale of ten square feet to quarter-inch at each point of division and marked on the scale. A curve, run fair from the stem through these marks to the stern, will form the curve of areas of external bulk."

(Rule 1.) "For external measurement to be ascertained when the vessel is on the stocks during the progress of building, or in dry dock, or otherwise on the ground, and according to the following rule, No. 1, (that is to say) determine the length between the perpendiculars by setting up from the under side of the false keel two-thirds ($\frac{2}{3}$) the medium height of tonnage deck, to cut the outside of the rabbets (or these produced) of the stem and stern post, these intersections squared down to the keel to give the positions of the perpendiculars, and having taken off the number of transverse sections of the hull, stated in the table."

"Compute the correct external bulk (exclusive of any wooden sheathing which may have been brought on to the proper planks of bottom) to the medium height of the tonnage deck, by means of a curve of areas constructed from the areas of the aforesaid sections; in the case of a break on the deck, the medium height to be ranged fair through in continuation of the deck, as if there had been no break. Record the correct mensuration in cubic feet thus obtained as the external bulk, to medium height of tonnage deck."

"To form scale of displacement.—Divide this bulk by 35, the quotient will represent the tonnage displacement of the hull immersed to that height above keel. By similar areas and curves, compute the tonnage displacement loaded to 2-3rds the height of deck, or between the perpendiculars, as well as the light line, immersed 1-3rd from the keel. These three quanti-

ties, set off on a horizontal scale of 10 tons to the quarter-inch, at their respective heights on a perpendicular scale of quarter-inch to a foot, a curve run from the keel through the three, will form a scale or table upon the tonnage displacement or weight of cargo carried."

Rule I.—Internal Measurement.

2. Then the hold, being first sufficiently cleared to admit of the required depths and breadths being properly taken, find the transverse area of such ship at each point of division of the length, as follows:—Measure the depth at each point of division, from a point at a distance of one-third of the round of the beam below such deck, or, in case of a break, below a line stretched in continuation thereof, to the upper side of the floor timber at the inside of the limber strake, after deducting the average thickness of the ceiling; then, if the depth at the midship division of the length do not exceed sixteen feet, divide each depth into four equal parts; "then measure the inside horizontal breadth at each of the three points of division, and also at the upper and lower points of the depth, extending each measurement to the average thickness of that part of the ceiling which is between the bilge planks and limber strake; also marking at the end of each horizontal breadth measured, the average thickness of the side, *i. e.* ceiling, frame timber, and outside plank, from which to compute the external area of each transverse section;" number these breadths from above (*i. e.* numbering the upper breadth One, and so on, down to the lowest breadth); multiply the second and fourth by four, and the third by two; add these products together, and to the sum add the first breadth and the fifth; multiply the quantity thus obtained by one-third of the common interval between the breadths, and the product shall be deemed the transverse area; but, if the midship deck exceed sixteen feet, divide each depth into six equal parts instead of four, and measure, as before directed, the horizontal breadths at the five points of division, and also at the upper and lower points of the depth; number them from above as before; multiply the second, fourth, and sixth, by four, and the third and fifth by two; add these products together, and, to the sum, add the first breadth and the seventh; multiply the quantity thus obtained by one-third of the common interval between the breadths, and the products shall be deemed the transverse area.

3. Having thus ascertained the transverse area at each point of division of the length of the ship as required by the above table, proceed to ascertain the internal space of the ship in the following manner:—"Number the areas successively, 1, 2, 3, &c., No. 1 being at the extreme limit of the length at the bow, and the last No. at the extreme limit of the length at the stern;" then, whether the length be divided, according to the table, into four or twelve parts, as in classes 1 and 5, or any intermediate number, as in classes 2, 3, and 4, "multiplying the second and every even-numbered area by four, and the third and every odd-numbered area (except the first and last) by two; add these products together, and, to the sum, add the first and last, if they yield anything;" multiply the quantity thus obtained by one-third of the common interval between the areas: record the product thus ascertained in cubic feet as the internal space under the tonnage deck.

To compute Register Tonnage.

"Add together the external bulk to the medium height of tonnage deck, and the internal space under the tonnage deck in cubic feet; divide the sum by 2, taking the mean of bulk and space in cubic feet as the basis of registered tonnage, to be deduced by the use of the factor ·30, ·31, or ·32

(hundredths) of that mean as the registered tonnage, approximating the old or builder's tonnage by the use of the divisor $35\frac{1}{2}$."

"All measurements to be recorded on paper ruled to a scale of a quarter of an inch to a foot on the section of the length at which they are measured, diagrams of each section to be formed at the line of measurement, these areas to be computed by any two of the four modes contained in the instructions, the correct areas to be formed into a curve of areas from the length of the tonnage deck. A scale of displacement, the area of midship section, and draft of water, to be formed on the certificate of survey, which is to be recorded in the diagrams of sections and curves of areas, and formed from a section of the frame ruled on a scale half an inch to a foot. A specification of the quality and scantling of the various materials used in the vessel to be filled in on the back of the certificate of survey; to be signed by the builder or owner, as well as the surveying officer."

22. Ships which, requiring to be measured for any purpose other than registry, have cargo on board, and ships which, requiring to be measured for the purpose of registry, cannot be measured by the rule above given, shall be measured by the following rule hereinafter called Rule II.:—

Rule II.—1. Measure the length on the tonnage deck from the outside of the outer plank at the stem to the aftside of the stern-post, deducting therefrom the distance between the aftside of the stern-post and the rabbet of the stern-post at the point where the counter plank crosses it; measure also the greatest breadth of the ship to the outside of the outer planking or wales, and then, having first marked on the outside of the ship on both sides thereof the height of the tonnage deck at the ship's sides, girt the ship at the greatest breadth in a direction perpendicular to the keel from the height so marked on the other side by passing a chain under the keel; to half the girth thus taken add half the main breadth; square the sum; multiply the result by the length of the ship taken as aforesaid; then multiply this product by the factor ·0018 (eighteen ten-thousandths) in the case of ships built of wood, and by ·0021 (twenty-one ten-thousandths) in the case of ships built of iron, and the product shall be deemed the register tonnage of the ship, subject to the additions and deductions hereinafter mentioned.

2. If there be a break, a poop, or other closed-in space on the upper deck, the tonnage of such space shall be ascertained by multiplying together the mean length, breadth and depth of such space, and dividing the product by 100, and the quotient so obtained shall be deemed to be the tonnage of such space, and shall, subject to the deduction for a closed-in forecastle mentioned in Rule I., be added to the tonnage of the ship under the tonnage-deck ascertained as aforesaid; and if the ship has three or more decks, the tonnage of each space between decks above the tonnage-deck shall be ascertained in the same manner as for the like spaces in Rule I., and added to the tonnage aforesaid.

No. 7.—Admiral Moorsom (*Member of the Committee*).

In answer to the Circular of Nov. 6th, 1856.

Highfield, Birmingham, Feb. 23, 1857.

My Dear Sir,—I shall not be able to attend your Committee to-morrow. I have considered the questions in Mr. Atherton's printed paper, and I cannot afford you much help in the form of categorical reply.

There does not seem to be much disposition on the part of owners of sailing vessels or steamers to stir against the present system of registration.

On many grounds, however, I think that every vessel should incur a penalty

which is loaded so as to sink below a certain draught of water; and that her registered tonnage should comprise the weight of water between her assigned load draught and that draught which she would have when fit for sea, with crew and stores and everything on board, except that by which she earns her freight. Supposing such a principle to be admitted, the method of determining such tonnage would not be difficult.

I annex an example. But the question at this moment is, how is this principle of registration to be tested, and, if sound, carried out?

The agitation of it, so that the public may some day see they have an interest in it, must do good, and I shall, therefore, be glad to subscribe towards the expenses of your association.

Next, as to the unit of HP. When a person wishes to buy an engine, he need not trouble himself about the nominal HP, but specifying the nature and extent of the work it is to do, he can bind the engine builder to results. The contractor, on his part, has his own rules for making the instrument. It then becomes a question of specific performance between the parties, with which the public is not concerned. But with the question of the improvement of engines and the improvement of vessels, the public has every concern, and improvement can make but slow and fitful progress when the power *exerted* and the power *given out* in any case are not known, or known only to a few persons, and that by special experiment only, and not by stated performance.

In the pamphlet I have had printed for private circulation, of which you have a copy, I have expressed my opinion on this question of the improvements of engines and vessels, and your Committee may probably coincide in my views.

I think then, that it is of little consequence to what unit we refer the expression HP, if in any given case we can know the power exerted; and it is the indicator power and its results, including the consumption of fuel, that is wanted.

Any measure of power must be incomplete without the weight of the fuel which is the originator of the power, and in any general expression we must include the boiler as well as the cylinder.

Such expression would consequently mean a given weight moved through a certain space in a certain time with a certain weight of coal.

Now, as yet we have no data for such an expression. I must apologise for so hasty and incomplete a statement, but I would not let the day pass without an acknowledgment of your note. Having returned home only on Saturday, and leaving home again tomorrow, I have not at present time to proceed further with the subjects of the printed letter.

I am, Sir, yours truly,

J. Yates, Esq. C. R. MOORSOM.

(ENCLOSURE.)

Let the dimensions of a vessel at her light draught ready for sea, except cargo, be—

Length	300 feet.
Breadth	50 „
Draught	15 „

Assume the coefficient of displacement, = 45.

Then, $\frac{L \times B \times D}{35} \times, 45 = 2892{\cdot}825$ tons.

Let the dimensions at load draught be—

Length	325 feet.
Breadth........................	53 „
Draught	22 „

Assume the co-efficient of displacement, = 62.

$$\text{Then, } \frac{L\times B\times D}{35}\times{,}62=6712{\cdot}74$$

$$2892{\cdot}825$$

$$\text{Tonnage for dues } \quad 3819{\cdot}915$$

The builder's displacement scale would furnish these particulars, and it should be the duty of the Customs Department to check that scale and verify the facts.

A table of co-efficients might be constructed on the ratios of length to breadth, and breadth to draught of water, which would enable every owner to ascertain the displacement at all draughts.

Memorandum on the Questions submitted in the Circular of Nov. 6th, 1856.

Having read the papers transmitted with Mr. Wright's letter of the 19th inst., I have something to qualify in my letter to Mr. Yates of the 23rd of February, and not much to add to it.

1st. I concur in the opinion that science has nothing to gain by legislation, except the repeal of the laws which impede her progress; and believing that the interference of authority in things which can be matter of bargain between man and man must always be pernicious, I would tolerate such interference only where no other security can be had against misdoing. On these principles I am disposed to let the present system of registration stand for all purposes of voluntary contract, but I think a shipowner should be taxed only in the measure in which he can receive freight; and as the displacement is the measure of the freight which a ship can take, it should also be the measure of tolls and dues. Moreover, as the public ultimately pay these charges, they are interested in the question.

In so far also as the system of registration may interfere with the best form of construction of vessels, it impedes science, in which also the public are concerned.

I adhere, however, to my opinion that for each vessel there should be a draft of water beyond which she should not be loaded, but, instead of a penalty, I would merely withhold the clearance. On this point, it would be useful to obtain facts as to any differences of opinion between the government agents and the other parties in cases of vessels with passengers.

I have heard of such differences.

The case of the *Royal Charter* is somewhat in point; after getting into the Bay of Biscay, she was compelled to return to port to be re-stowed.

When on board this ship, before she received her cargo, I pointed out to the authorities of the ship then on board, the risk of such a contingency, and how to guard against it; for, if I understood the letters of Dr. Scoresby, (himself a seaman and on board), which appeared in the *Times*, the ship was not only two feet too deep but was overweighted in her fore-body. Now, how could the underwriters protect themselves in such a case?

Would the policy be vitiated? Was the premium higher in consequence of such a known contingency as overloading and misloading?

How could the second-class passengers, who were represented as washed

out of their berths, protect themselves beforehand; and what remedy had they after the fact, or what compensation?

If the displacement principle were adopted, tables might be constructed for all known forms of vessels, which would give the displacement at any draught of water, and upon the difference of light and load draught the duties should be payable: this would set at rest the question between sailing vessels and steamers.

Secondly.—As to a unit of HP. Here the commercial part of the question resolves itself into a matter of bargain, and neither buyer nor seller can be benefited by interference. The buyer has but to specify the work he requires, and to make his contract accordingly. But the scientific part of the question assumes another aspect.

Improvement can make but slow and fitful progress when the power *exerted* and the power *given out* are known only to a few of the initiated. What science wants to know in each case is, the indicator power and its results, including the consumption of fuel. Any measure of power which does not embrace the weight of fuel, which is the originator of the power, must be incomplete.

Any general expression must include the boiler as well as the cylinder, and it would mean a given weight moved through a certain space in a certain time, with a certain weight of fuel. We have not as yet data for such an expression.

The accompanying pamphlet, which I have had printed for private circulation, may perhaps throw some light upon this subject, and I have marked the passages bearing on the immediate question of power.

I have now before me a table printed by the Admiralty last year, and showing "results of trials made in her Majesty's screw ships and vessels." These results are useful as far as they go, but they do not go far enough, and the particulars of the table might be simplified and amended. They involve a theory, whereas facts alone are wanted. The trials were made in smooth water only, and do not contain any account of the consumption of fuel.

The passages marked in the pamphlet and the tables A and B will show how necessary it is to have the performances of vessels and engines *at sea*, in order to institute any comparisons towards the deduction of laws, and that the consumption of fuel is indispensable.

March 24, 1857. C. R. Moorsom, Rear Admiral.

No. 8.—Mr. James Yates (*Member of the Committee*).

To the Shipping Registration Committee of the British Association.

I am very desirous of directing the attention of the Shipping Registration Committee to the following considerations:—

The party, if it may be called a party, which we considered as opposed to ourselves, and which we may probably regard as represented by Mr. G. Moorsom, do not appear to be in such entire opposition as may at first be imagined, and certainly, we are not entirely opposed to them. On the contrary, we appear to agree in the most important and fundamental points.

1. We agree in regard to the necessity of internal measurement as an element of tonnage registration, being the space inside a vessel, or under cover, which may be used to carry either cargo or passengers.

2. We agree in regard to Sterling's rule as a recognized method of admeasurement, available for calculating the entire contents of a ship of any form, measured either internally or externally.

3. We agree that neither internal nor external measurement does, of itself, provide any security against the construction of weak thin-sided ships.

4. We agree with the remarks in Mr. Moorsom's Treatise on Tonnage, in regard to the great advantages of the registration of displacement, or outward measurement between the light and load water-lines, as showing the actual weight which any vessel will carry.

These advantages cannot be more distinctly stated than they are by Mr. Moorsom, in the following remarks on the measurement of keels, and the method of marking the load water-line with nails, according to weights actually placed on board, as prescribed by 6 and 7 William and Mary, A.D. 1694, and by 15 George III. c. 27.

"This being a measure of pure and unerring displacement, free from the possibility of evasion, and giving the exact dead weight of the cargo shipped, whatever may be the form or construction of the vessel, it offers no inducement to the building of one kind of form more than another; and the consequence is, that many of these peculiar vessels are remarkable for their sailing capabilities.

"Although the process of 'admeasuring and marking,' to which these vessels are still legally directed to be submitted, involve neither the taking of measurements nor computation, and can therefore, it may be supposed, scarcely be termed a mode of admeasurement in the usual acceptation of the operation ; yet it is, nevertheless, essentially and absolutely, the most correct measurement possible of the displacement, or external cubature of that part of the vessel which lies, or is contained, between the light and load lines of floatation, that is, of the cargo shipped; and is, therefore, not only an assurance of the security of the public revenue to be derived from the export of coals, but is found also to tend greatly to the general accommodation of the trade in which these vessels are engaged; and from what has been already predicated of their sailing capabilities, the process is, moreover, an eminent and satisfactory, though it may appear an humble example, that an operation founded on truth, *without the possibility of evasion*, is an operation without influence in the formation of ill-formed vessels*."

In a subsequent chapter, Mr. Moorsom treats with great ability the subject of displacement, showing how it is in practice calculated by Sterling's rule, and with how great advantage this registration of displacement may be applied to merchant ships, as is already done in men-of-war by recording the scale of displacement of all ships in the Royal Navy. See ch. V., p. 113-148. These statements of Mr. Moorsom clearly establish the practicability of ascertaining the weight that ships will carry as based on the measurement of displacement, and recording the same, together with the measurement of internal roomage.

5. Another principle of the utmost importance, in which, I trust, we are agreed, and with the statement of which I shall conclude these remarks, is, that the measurement of tonnage should be international, in other words, that, as far as possible, it should be the same for all nations, and adopted with the consent of all. Mr. Moorsom asserts the value of the principle, and quotes an American author, Griffiths, a ship-builder of great experience, who entertains the same cosmopolitan views. He quotes that admirable memorial of the Council of the Society for the Encouragement of Arts, Manufactures, and Commerce, which recommends to the Lords of the Treasury, A.D. 1853, the consideration of the best means of promoting the adoption throughout the world of a uniform decimal system of measures, weights,

* 'A Brief Review and Analysis of the Laws for the Admeasurement of Tonnage,' by G. Moorsom. 2nd edition. London, 1853, pp. 15, 16.

and coins, and which especially insists on the great advantage and convenience of the Metrical System. As Mr. Moorsom also alludes, in encouraging language, to the sentiments "of our active-minded Transatlantic rivals," I will add, that not a few of the most distinguished among them have urged upon their government an examination of the merits of the same system*. Moreover, Mr. Allan Gilmour points out the necessity "of having a law, under which the tonnage of all vessels entering our ports, whether British or foreign, shall be computed in the same way†."

In pursuance of these "cosmopolitan views" of Mr. Moorsom and Mr. Gilmour, I wish to offer some considerations in favour of the adoption of the metrical ton in place of the British ton, for the registration of the weight tonnage of ships. It is probable that this mode of registration, if adopted by Great Britain, would lead in a short time to perfect uniformity throughout the world.

The metrical ton of 1000 kilogrammes is now recognised, and in part practically adopted by a considerable number of the principal mercantile nations. It is established in France, Belgium, Holland, Prussia, Hamburg and the other Hanseatic ports, Denmark, the kingdom of Sardinia, Lombardy, Algeria, Greece, and several South American States. Its adoption after a few years has been decreed by the governments of Spain and Portugal.

Besides Great Britain and its dependencies, the only commercial nations of importance, which do not already use the metrical ton, are the United States of America, Russia, Sweden, Turkey, and Egypt. There can be no doubt that these latter countries would adopt it, if Great Britain led the way.

The metrical ton being the weight of a cubic metre of water equal to 1000 kilogrammes, while the British ton is nearly 1015 kilogrammes, or $1\frac{1}{2}$ per cent in excess, it is evident that no objection can arise from the adoption of the former as the unit of ship's tonnage by weight except the temporary inconvenience which accompanies every change whatsoever. A ship of 1000 tons British weight would simply be 1015 metrical tons.

According to a return issued by the Board of Trade, the exports from the United Kingdom in 1855, consisting of British and Irish produce and manufactures, amounted in value to £95,688,085, or nearly £96,000,000. The countries which use the metrical ton, and are included in this statement of exports, are as follows:—

	£
Prussia, Hanover, and the Hanseatic Towns	9,787,600
France	6,012,658
Holland	4,558,210
Sardinia	853,916
Lombardy	717,713
Belgium	1,707,693
Portugal	1,475,713
Spain	1,268,815
Denmark	759,656
New Grenada	588,935
Mexico	585,898
	£28,315,207

* See my 'Narrative of the Origin and Formation of the International Association for obtaining a Uniform Decimal System of Measures, Weights and Coins.' I have republished at pp. 51, 52, the memorial referred to; and at pp. 9—11, 47—49, I have given an account of similar efforts in the United States by President Adams, the Hon. George Bancroft, and others.

† 'Remarks on the Tonnage Admeasurements of Ships,' published in Moorsom's 'Brief Review,' pp. 175—179.

Thus, the portion of these exports sent to countries using the metrical ton amounts to above £28,000,000. A considerable proportion of the countries to which the remaining £68,000,000 of goods were exported does not use either the English or the metrical ton, but some other weight. So large a proportion of our foreign commerce being already carried on with nations using the metrical ton, it appears highly probable that the adoption by Great Britain of the metrical ton as the unit of weight tonnage, would speedily lead to its universal adoption throughout the world. Nor can it be questioned, that this would be a most proper adjunct to the recent alteration of the Navigation Law, by which the ships of all countries are permitted to carry goods and passengers to and from Great Britain with unrestricted freedom. A common method of computing the carrying powers of ships, would be a manifest and indisputable advantage. For statistical information, the adoption of the metrical ton weight is indispensable. At two great statistical congresses, Brussels, 1853, and Paris, 1855, it was recommended that the weights and measures of the Metrical System should be universally employed as common terms of comparison, reference being made more especially to the tonnage of ships*.

Let us now consider the advantages of the metre as a linear measure, and of the metrical ton based upon it, independently of their extensive adoption throughout the world. According to the English method, the measures of length are generally computed in feet, inches, and eighths of an inch; or, if recourse is had to decimals, as directed by the late Mercantile Shipping Act, in feet and hundredths of a foot. The use of a measuring-line, divided into metres and centimetres, appears to present at least equal advantages, and would be simple, easy, and commodious in the extreme for tonnage measurements, having all the recommendations of a decimal system.

If the metrical ton be adopted as the base of ships' tonnage, the displacement between the light and load water-lines, expressed in cubic metres and centimetres, will give the metrical tonnage without any further trouble and with perfect exactness, because a metrical ton is the weight of a cubic metre of water. This remarkable facility is obtained, because in constructing the Metrical System, care was taken to adjust the weights so that they might have a direct and simple relation to the measures. In the English weights and measures this principle has been disregarded.

Suppose now that we follow the new law, the Mercantile Shipping Act of 1854, which, however, is never likely to extend itself to the world at large, because in this law "the ton" is a palpable misnomer, not being a weight of any kind, but a certain extent of internal space. Under this law the cubic contents of every part of a vessel, adapted to carry passengers or cargo, are ascertained either by Sterling's rule or some other approved formula, and are expressed in cubic feet. The number of cubic feet is then divided by 100, this number having been adopted as the divisor in order to assimilate the new tonnage registration to the former tonnage registration.

If we apply the metre as the unit of linear measure, we shall find the internal space in cubic metres instead of cubic feet, and we can easily reduce the one measure to the other, because a cubic metre being equal to 35·32 cubic feet, the number of cubic metres multiplied by the decimal ·3532, will give the number of tons measure at the rate of 100 cubic feet to the ton, according to the principle of the new law.

It thus appears that the metrical ton, differing from the British weight of the same name only by about 15 parts in 1000, whereby a ship capable of

* See Rouher and Legoyt, 'Compte Rendu de la Deuxième Session du Congrès Internationale Statistique.' Paris, 1856, 4to., p. xv., 169-172, 192, 193, 256, 257.

carrying 1000 tons weight British, would carry 1015 metrical tons, and be registered accordingly, recommends itself, not only by its use among many of the chief trading nations, but by its adaptation to the requirements of international commerce, to the convenience of mariners, and, most especially, to the measurement and registration of vessels of all kinds as respects their capabilities for carrying weight: to which it must be added, that the system of weights and measures to which this ton belongs, and which is every year extending through the world, is the only system which appears at all likely to become universal; so that the metrical ton weight must be adopted as the basis of tonnage registration, if international tonnage is to be pursued as an indispensable part of a really good method.

JAMES YATES.

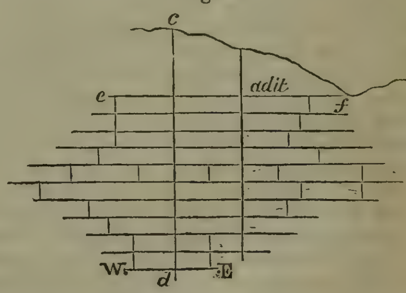
Lauderdale House, Highgate, Feb. 14, 1857.

Report on the Temperature of some Deep Mines in Cornwall. *By* ROBERT WERE FOX, F.R.S., G.S.

IN compliance with the request of the Committee of the British Association, I have had further experiments made on the temperature of some deep mines in Cornwall by careful observers, and I have now to report the results of their investigations*. But before I do this, it may perhaps be well to allude to the method of working, or rather exploring a metalliferous vein or "*lode*" in this county. The horizontal bearing of most of the lodes is from east to west, or rather from northward of east to southward of west; and they descend into the earth to an unknown depth, and much more often in an *inclined* than a *vertical* direction, intersecting the different rocks which occur in their courses. The miners work a lode by means of shafts, and galleries or "*levels*," which latter, being on the course of the lode, do not usually succeed each other in a vertical, but in an inclined direction.

Fig. 1.

Fig. 2.



Let fig. 1, *a*, *b*, represent a north and south section of a lode inclined towards the north; *c*, *d* an engine-shaft through which the water is pumped

* I am indebted to my friend William Hustler of Rosemerryn, near Falmouth, for the results obtained in the United Mines, and most of those in Fowey Consols;—to Captain J. Puckey, Manager of Fowey and Par Consols, for experiments in those mines;—to Captain Charles Thomas, Manager of Dolcoath, for an experiment there; to Captain Jennings of Tresavean, for some made in that mine in 1853; and to Henry Peters of Lanner, near Redruth, for the other experiments in Dolcoath, in Levant, and Botallack Mines.

up to the adit *e*, *f*, from the bottom or "*sump*" *d* (figs. 1 & 2), and from cisterns placed at various intervals in the shaft, the water which enters the levels being conducted into the cisterns, and thereby prevented from falling to the bottom of the shaft. From the adit, the water is discharged into a valley, or near the sea shore. The horizontal lines in fig. 1 represent "*cross-cuts*" or N. and S. levels, which connect the engine-shaft with the levels at right angles to them, as shown in fig. 2. These latter, on the course of the lode, are usually about ten fathoms apart, and they are connected together by many short shafts inclined with the lode. There are also other shafts from the surface to the deep levels, through which the ore is drawn up, ventilation promoted, &c. In most of the deep mines several lodes are worked, and each by means of a similar series of levels, shafts, &c., which are connected with the former series by "*cross-cuts*," so that one engine-shaft may often serve for two or more lodes. The deepest levels in a mine are generally much less extended than those above them, as shown in fig. 2, and the quantity of water in them is often comparatively small, the upper water being in a great degree cut off by the superior levels, and conveyed to the cisterns through the latter. The temperature of the water that flows into the ends of the deepest levels is generally as high, or nearly so, as that of the rocks and lode, and more often higher, which it may be presumed it would not be if much of the upper water were mixed with it. Most of the experiments were made at or near the ends of the deepest level in each of the respective mines, as at E. and W., fig. 2.

The thermometers employed were obtained for me by Professor Phillips, from Casella, and were, I need scarcely say, accurately graduated.

They were placed in holes from 15 to 20 inches deep in the rocks and lodes, which were carefully closed up with clay, tow, or cotton. After the thermometers had been so left from half an hour to an hour, they were withdrawn for an instant for the temperature to be read off, and were often again left in the holes for some time longer; but as no further change was observed at the second reading, this precaution was latterly dispensed with.

In taking the temperature of the water, the most copious springs at their sources or influx into the levels were selected, if near the stations where the other observations were made; and the temperature of the surrounding air was also ascertained.

The mines visited are situated in different parts of the county, ranging from near Fowey, to St. Just, a little to the north of the Land's End, a distance of about fifty miles.

To begin with Fowey Consols* copper mine, situated near Fowey, as being the most easterly one.

The deepest level in this mine was reported to be 328 fathoms under the surface, and about 298 fathoms below the sea-level; but the influx of water interfered with any experiments being made in this part of the mine, which is the more to be regretted, as perhaps there are few if any mines elsewhere so deep in reference to the level of the sea, although there are many deeper from the surface of the ground.

At 268 fathoms below the surface, water issued from a copper lode at

* Capt. J. Puckey calculates that the total length of all the levels on

the courses of the lodes in this mine amounts to	153 miles.
Of the *cross*-courses or levels, N. and S.	22 miles.
And of the shafts	7 miles.
	182 miles in all.

96°·5 Fahr.; the lode* was 95°·5 and the air 95°·2: no persons at work near the place.

In a level 288 fathoms deep, another lode was 94°, the adjoining rock 93°, and the air 91°·5: no water, and the containing rock "*killas*."

Par Consols is situated near Par on the shores of the English Channel, and produces copper and tin in "*killas*." Its deepest level, when visited, was 208 fathoms from the surface, and about 178 fathoms under the sea-level: the lode in it was at 84°, the rock 84°, and the air 82°. The part of this mine which produces tin was 128 fathoms beneath the surface at its deepest level, and there the lode was at 74°, the rock near the lode 74°, the air 75°, and the water 72°.

The United Mines in the parish of Gwennap have yielded much copper ore in "*killas*." At the eastern end of a level, 255 fathoms under the surface, and nearly 200 fathoms below the sea-level, a stream of water gushing out of a rich copper lode, called the north lode, was lately found to be at the temperature of 116° Fahr., and the neighbouring rock and air were at 106°. In another level, also 255 fathoms deep, worked on a parallel lode, southward of the former, in which there was very little water, the rock was 82°·5, and the air 82°.

I have had no recent information relative to the temperature at the bottom of the mine, but in 1853 the rock was 94°, the air 90°, and the depth 275 fathoms. At that date the stream of water in the eastern end of the level, 255 fathoms deep, was at 109°, or 7° less than now that the level has been further extended. In 1846, when the level was still less advanced towards the east, the spring of water, discharging as was then estimated 94 gallons in a minute, was at 106°·3, and the air 104°·2. At that time I examined some of the water and found 15 grains of common salt and chloride of lime in a quarter of a pint of it, in nearly equal proportions; but no metallic salt could be detected. This mine is several miles from the sea.

In 1853 I had some observations repeated in Tresavean, to ascertain in what proportion the temperature had increased with the increased depth since 1837. This mine is in the parish of Stythians, about eight miles to the N.W. of Falmouth, and has been very productive of copper, found mostly in granite, and but very little in killas. The bottom level was 352 fathoms, or 2112 feet under the surface, which is more than any other mine in Cornwall, and about 1750 feet below the sea-level, or rather less in this respect than Fowey Consols. The lode in this deep level, at its eastern extremity, was at 90°·5, the thermometer having been long kept in a dry hole, closed at the top; the contiguous granite 91°·5, the hole rather moist, the air 91°·5, and a small spring of water flowing from the lode into the level, 93°·5. In 1837 the deepest level in this mine was 262 fathoms, or 1572 feet beneath the surface, and the rock there was then found at 82°·5.

Dolcoath, in the parish of Camborne, has been a very productive mine of copper and tin ores, and now yields much of the latter from its deepest parts, the containing rock there being granite, with killas nearer the surface. The deepest level on the north lode was 272 fathoms below the surface, and extended only about four fathoms on each side of the engine-shaft. The rock near the eastern end of this level was at 73°·5, the air 71°·7, and the water 73°. At the western end the rock was 73° on one side of the level, and 73°·5 on the other, the air 73°, and the water, the quantity of which was *very small*, 72°·7. At about three fathoms further south, and the same depth, another

* When the temperature of the *rocks* or of the *lodes* is mentioned in this Report, it is meant that the thermometers were placed in holes in them for half an hour or more, and that the other precautions already referred to were observed.

lode was worked, the level extending to about fourteen fathoms to the westward of the engine-shaft. There the granite was found to be at 79°·5, and the water, which was much more abundant than in the other level, 79°·5, while the air was at 78°. Two men at a time worked near each of the stations in both levels. The pumps discharged only about 190 gallons of water per minute from the mine.

In 1821–1822 the deepest level in Dolcoath was 230 fathoms from the surface, and I then had an accurate thermometer, 4 feet long, kept in it more than a year and a half, with the bulb sunk 3 feet in the lode, and it varied from 75° and 75°·5 to 76°·5 and 77°; an occasional influx of water having caused a temporary rise of the mercury to the extent of a degree or more. This temperature being from two to three degrees higher than the rock, was lately found by H. Peters to be at an *increased* depth of 42 fathoms: I begged Captain Charles Thomas, the manager of the mine, to have a thermometer left for some days in a hole in the rock near one of the ends of the deepest level on the north lode. This he has done, and he reports that the temperature did not vary from 73°, although the thermometer was left there a week, and the top of the hole was well closed, thus confirming H. Peters' observations.

The water near the bottom of the engine-shaft in 1822 was at 82°, at 239 fathoms below the surface, and this year (1857) it was at 82°·5, at 278 fathoms deep.

Levant copper and tin mine, in St. Just parish, is nearly twenty miles to the west of Dolcoath, and is close to the sea. Its deepest level is 255 fathoms below the surface of the ground, and nearly 230 fathoms beneath the sea-level, having been horizontally extended under it through killas. The temperature of the rock near the end of this level was 84°·7 on one side of the latter, and 85°·5 on the other; the water 85°·5, and the air 85°. No men had been employed in this level for some time. There was very little water there, and indeed only about 60 or 70 gallons were discharged per minute from the mine.

In 1853 the temperature of the rock in this level, when it was not extended so far westward under the sea, was reported to me to be 87°, and the granite rock at the same level, eastward of the shaft, 74°.

Botallack copper and tin mine is situated at the north-western extremity of Cornwall, in the parish of St. Just, and the engine-house is built on a rock which is washed by the sea. The western levels have been worked through killas far under the Atlantic, one of them extending more than half a mile from the shore. Two men and a boy were employed in the deepest level, which was less advanced from the shore. It was 188 fathoms below the ground, and about 180 fathoms under the sea-level. The rock near the end of the level was 79° on one side of it, and 79°·5 on the other, the air 81°: no water at that station, and but little comparatively in the mine.

The foregoing results exhibit great differences in the rates of increase in the temperature in different mines, and also in different parts of the same mine. If we arrange the mines in the order of their respective depths, including those only in which experiments were made in the *rocks* or *lodes* at their *deepest* levels, the following will be the ratios in feet, in descending from the surface, in which the temperature was augmented one degree Fahr. from 50°, the mean temperature of the climate.

Mines.	Depths in feet.	Dates.	Temperatures.	Increase of 1° in descending.	Rocks.
Par Consols (tin part) ...	768	1837	74° −50=24°	32 feet	Killas.
Botallack, C. and T.......	1128	1837	79 −50=29	39 „	Killas.
Par Consols (copper part)	1248	1837	84 −50=34	36·7 „	Killas.
Dolcoath, C. and T.	1380	1822	75·5 −50=25·5	54 „	Granite.
Levant, C. and T.	1530	1853	74 −50=24	63·7 „	Granite.
Levant, C. and T.	1530	1853	87 −50=37	41·3 „	Killas.
Levant, C. and T.	1530	1857	85 −50=35	43·7 „	Killas.
Tresavean, C................	1572	1837	82·5 −50=32·5	48·4 „	Granite.
Dolcoath, C. and T.	1632	1857	73 −50=23	71 „	Granite.
Dolcoath, another lode...	1632	1857	79·5 −50=29·5	55·3 „	Granite.
Tresavean, C................	2112	1853	90·5 −50=40·5	52·1 „	Granite.

On comparing the results obtained in Dolcoath in 1821–1822 and 1827, it appears that the temperature was increased only 4° in one level with an increased depth of 252 feet, giving a ratio between the stations of 1° increase in 63 feet; and in another level the temperature was actually 2° to 2°·5 less than in 1822, although 252 feet deeper than the mine was then. These experiments were made with great care, and this exceptional case may probably be due to the greater hardness and compactness of the lode in the deeper level, and the diminished quantity of water.

The depth of Tresavean was increased 540 feet between 1837 and 1853, and the temperature 8°·5 in the deepest level, or in the ratio of 1° in 63·5 feet.

I have not included in the Table the results recently obtained in the United Mines or Fowey Consols, the experiments not having been made in their deepest levels; but the hot spring at 116°, at the depth of 255 fathoms in the United Mines, gives a ratio of 1° increase in 23·2 feet, and the rock in another level, also 255 fathoms deep, 1° in 47 feet.

In 1853 the bottom of the United Mines was 275 fathoms below the surface, and the rock 94°, or in the ratio of 1° in 37·5 feet. At Fowey Consols, the rock, in a level 288 fathoms deep, was at 93°, or in the ratio of 1° increase in 40·2 feet.

Widely as the ratios differ from each other in different mines and in different parts of the same mine, the results tend to confirm the statement that the temperature in general increases less rapidly in deep mines than in those which are of inferior depth; and this is more especially observable when experiments are made from time to time at the bottom of a mine as the depth increases, unless the results be modified by an increase of water coming from greater depths. It is not, however, to be inferred that the diminishing ratio of temperature in descending into the earth extends to an indefinite depth; it may, on the contrary, and probably does, increase much more uniformly at depths where the circulating water has little or no influence. A copious spring of warm water gushing from a vein, is hailed by the miners as a favourable indication of the proximity of ore, and so is a pervious, or "hollow" lode; but the former clearly results from the latter, the warm water rising from greater depths through the lode.

These subterranean springs are often nearly as free from saline matter as those occurring at the surface; in some I have found common salt and chloride of lime, especially in water taken from the deep levels of Poldice and Wheal Unity, and the hot spring at the United Mines. My friend William Hustler has recently examined the latter, and he reports that it "still contains a large quantity of chloride of sodium, and a considerable quantity of chloride of calcium, with traces of the sulphates of lime and

magnesia; no iron or copper." All these mines are several miles from the sea. The water from the deepest level in Levant and Botallack also contained some common salt, and was slightly saline to the taste; but the proportion was much less than might have been expected in excavations extending so far under the sea. I have examined the water from numerous mines, taken immediately from the *springs* at their *entrance* from the veins into the levels, and I have not detected the presence of any metal, except in some instances a very little sulphate of iron, and traces of the sulphate of zinc, on two or three occasions. On the other hand, it may be observed, that the water not coming directly from the *springs*, but which is collected more or less in *pools* in the levels, often contains metallic salts derived from the ores in the levels broken from the lodes, and exposed for a time in heaps to the joint action of air and water.

The phenomena observed in mineral veins, however, afford strong presumptive evidence that the water circulating through them has, from time to time, varied much in its properties, sometimes depositing minerals, and at others decomposing them.

Captain J. Puckey has, at my request, made an experiment on the temperature of the rock at the end of a "cross-cut" in Fowey Consols. The *end* was dry, 60 fathoms from the lode, distant from other workings, and 140 fathoms deep. He thinks that they will have to extend the cross-cut 20 fathoms further to intersect another lode. The thermometer remained an hour in a hole of the rock, the top of which was closed with clay; and on being withdrawn, the mercury was found at 82°, and in the air it stood at 78°. Captain John Kitto has also made experiments in Swanpool lead mine near Falmouth; temperature of rock 58° at the end of a dry cross-cut, 34 fathoms northward of the lode, and 55 fathoms deep. In another cross-cut, the end of which is 14 fathoms to the south of the lode, and 60 fathoms below the surface, the rock was at 60°, air 64°, and the water 59°. The presence of the latter probably indicated the proximity of another lode. This mine is 80 fathoms deep, and both the mines are in killas.

I may remark, in conclusion, that on comparing the specific gravities of pieces of different rocks taken from the deepest parts of some of the mines, with others of the same kind occurring at or near the surface, I have not found any decided differences between them in this respect.

De quelques Transformations de la Somme $\Sigma_0^{t^{-\alpha}} \frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, *$\alpha$ étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $\alpha^{t|+1}$ désignant le produit des* t *facteurs* $\alpha(\alpha+1)(\alpha+2)$ *&c.* $\ldots(\alpha+\mathrm{t}-1)$. *Par* G. PLARR, *Docteur ès Sciences de Strasbourg.*

[A Communication ordered to be printed entire among the Reports of the Association.]

Dans un mémoire sur la série

$$f(\alpha, \beta, \gamma)=1+\frac{\alpha.\beta}{1.\gamma}+\frac{\alpha(\alpha+1)\beta(\beta+1)}{1.2.\gamma.(\gamma+1)}+\frac{\alpha^{3|+1}\beta^{3|+1}}{1^{3|+1}\gamma^{3|+1}}+\text{\&c.}$$

Gauss a donné une expression de la somme de cette série pour des valeurs

quelconques de $\alpha\beta\gamma$, satisfaisant seulement à la condition de convergence $\gamma-\alpha-\beta>0$.

Dans le cas où α est entier négatif (et que du reste, γ, s'il est de même entier négatif, est en valeur absolue plus grand que $-\alpha$), la série se termine, et peut s'exprimer par un quotient de deux factorielles,

$$f(\alpha, \beta, \gamma)=\frac{(\gamma-\beta)^{-\alpha|+1}}{\gamma^{-\alpha|+1}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Désignons par analogie par $F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)$ la série proposée de six factorielles, c'est à dire, posons

$$F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)=\Sigma_0^\infty{}_t\ \frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}.$$

Dans le cas où α est entier négatif (et que γ et ϵ, s'ils l'ont l'un ou l'autre entiers négatifs, sont en valeur absolue plus grands que $-\alpha$), la série se termine au $1-\alpha^{\text{ième}}$ terme, et son expression est susceptible d'un certain nombre de transformations, dont voici quelques unes:—

$$F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)=\frac{(\gamma-\beta)^{-\alpha|+1}}{\gamma-\alpha|+1}\,F\left(\frac{\alpha,\ \beta,\ \epsilon-\delta}{\alpha+\beta-\gamma+1,\ \epsilon}\right). \quad . \quad . \quad . \quad . \quad . \quad (a)$$

$$F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)=\frac{(\gamma-\beta)^{-\alpha|+1}(\epsilon-\beta)^{-\alpha|+1}}{\gamma^{-\alpha|+1}\epsilon^{-\alpha|+}}\,F\left\{\begin{matrix}\alpha,\ \beta,\ \alpha+\beta+\delta-\gamma-\epsilon+1\\ \alpha+\beta-\gamma+1,\ \alpha+\beta-\epsilon+1\end{matrix}\right\} (b)$$

$$F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)=(-1)^\alpha\frac{\beta^{-\alpha|+1}\delta^{-\alpha|+1}}{\gamma^{-\alpha|+1}\epsilon^{-\alpha|+1}}\,F\left\{\begin{matrix}\alpha,\ \alpha-\gamma+1,\ \alpha-\epsilon+1\\ \alpha-\beta+1,\ \alpha-\delta+1\end{matrix}\right\}. \quad . \quad . \quad (c)$$

Les formules (b), (c) sont des consequences de (a).

Dans le cas où $\epsilon-\delta$ est entier négatif, et en valeur absolue plus petit que $-\alpha$, la formule (α) donne celle-ci:

$$F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)=\frac{(\gamma+\epsilon-\beta-\delta)^{\alpha|+1}}{\gamma-\alpha|+1}\,F\left\{\begin{matrix}\epsilon-\delta,\ \alpha,\ \epsilon-\beta\\ \gamma+\epsilon-\beta-\delta,\ \epsilon\end{matrix}\right\}. \quad . \quad . \quad . \quad (d)$$

Lorsque $\alpha+\beta+\delta-\gamma-\epsilon+1=0$, la formule ($b$) donne le résultat suivant, basé sur la remarque que $F\left(\frac{\alpha,\ \beta',\ 0}{\gamma',\ \epsilon'}\right)=1$ lorsque $\delta'=0$; savoir,

$$F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)=\frac{(\gamma-\beta)^{-\alpha|+1}(\epsilon-\beta)^{-\alpha|+1}}{\gamma^{-\alpha|+1}\epsilon^{-\alpha|+1}}\times 1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (e)$$

Le cas où les bases α, β, &c. satisfont à la relation $\alpha+\beta+\delta-\gamma-\epsilon+1=0$ est donc un des cas dans lesquels la fonction $F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)$ peut se sommer sous forme monôme, et s'exprimer par un quotient de factorielles.

Voici maintenant la démonstration de la formule (a). La formule (1) donne

$$f\left(\frac{a,\ b}{c}\right)=\Sigma_0^{-a}{}_s\ \frac{a^{s|+1}b^{s|+1}}{1^{s|+1}c^{s|+1}}=\frac{(c-b)^{-a|+1}}{c^{-a|+1}}.$$

Identifions avec le 3$^{\text{e}}$ membre le quotient $\frac{\delta^{t|+1}}{\epsilon^{t|+1}}$ dans l'expression de $F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)$. Nous devions poser

$$-a=t,\quad c-b=\delta,\quad c=\epsilon.$$

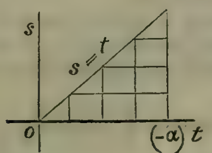
De là

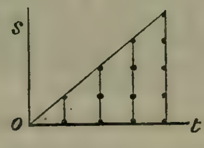
$$F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)=\sum_{t=0}^{-\alpha}\frac{\alpha^{t|+1}\,\beta^{t|+1}}{1^{t|+1}\,\gamma^{t|+1}}\sum_{s=0}^{t}\frac{(-t)^{s|+1}(\epsilon-\delta)^{s|+1}}{1^{s|+1}\,\epsilon^{s|+1}}.$$

Intervertissons l'ordre dans la sommation par rapport à t et à s. À cet effet donnons une signification géométrique à la double sommation exprimée par

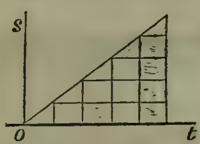
$$\sum_{t=0}^{-\alpha}\sum_{0}^{t}\phi(t,\ s).$$

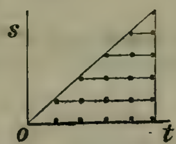
Concevons les valeurs $\phi(t, s)$ disposés par points dont les abscisses soient t, et les ordonnées s. L'ensemble de ces points est limité par un triangle





dont l'hypoténuse a pour équation $s=t$, et les deux cadettes sont $s=0$ et $t=-\alpha$; car pour chaque valeur de t considéré comme indice indépendant, il faudra donner à s les valeurs depuis $s=0$ jusqu'à $s=t$. Si l'on considère s





comme indice indépendant, il faudra pour chaque valeur de s donner à t les valeurs depuis $t=s$ jusqu'à $t=-\alpha$. On aura donc

$$\sum_{t=0}^{-\alpha}\sum_{s=0}^{t}\phi(t,\ s)=\sum_{s=0}^{-\alpha}\sum_{t=s}^{-\alpha}\phi(t,\ s),$$

d'où

$$F\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}=\sum_{s=0}^{-\alpha}\sum_{t=s}^{-\alpha}\frac{\alpha^{t|+1}\beta^{t|+1}(-t)^{s|+1}(\epsilon-\delta)^{s|+1}}{1^{t|+1}\,\gamma^{t|+1}\,1^{s|+1}\,\epsilon^{s|+1}}.$$

Introduisons un nouvel indice u lié à s, t par $t=s+u$. Les limites de u seront pour $t=s$, $u=0$; pour $t=-\alpha$, $u=-\alpha-s$. De plus,

$$\frac{(-t)^{s|+1}}{1.^{t|+1}}=\frac{(-1)^{s}}{1^{u|+1}}$$

$$\alpha^{t|+1}=\alpha^{s|+1}\times(\alpha+s)^{u|+1},\ \text{\&c.}$$

D'où

$$F\left(\frac{\alpha,\ \beta,\ \delta}{\gamma,\ \epsilon}\right)=\sum_{s=0}^{-\alpha}\frac{\alpha^{s|+1}\beta^{s|+1}(\epsilon-\delta)^{s|+1}}{1^{s|+1}\gamma^{s|+1}\epsilon^{s|+1}}\times(-1)^{s}\sum_{u=0}^{-\alpha-s}\frac{(\alpha+s)^{u|+1}(\beta+s)^{u|+1}}{1^{u|+1}(\gamma+s)^{u|+1}}.$$

La somme $\sum_0^{u^{-\alpha-s}} \phi(u)$ est de la forme

$$f\frac{\alpha+s,\, \beta+s}{\gamma+s} = \frac{(\gamma+s-\beta-s)^{\cdot -\alpha-s|+1}}{(\gamma+s)^{-\alpha-s|+1}}.$$

Cette quantité, toute réduction faite, devient

$$\frac{(\gamma-s)^{-\alpha|+1}}{\gamma^{-\alpha|+1}} \times \frac{\gamma^{s|+1}(-1)^s}{(\alpha+\beta-\gamma+1)^{+s|+1}}.$$

En la substituant dans l'expression précèdente de $F\left(\frac{\alpha,\, \beta,\, \delta}{\gamma,\, \epsilon}\right)$, et en remarquant que $(-1)^{2s}=+1$, il en résulte la formule (a).

Pourque la formule (a) ne soit pas illusoire, il faut que $\alpha+\beta-\gamma+1$, s'il est entier négatif, ne sort pas en valeur absolue moindre que $-\alpha$, ou moindre que $\epsilon-\delta$ si par hasard cette dernière quantité est entière négative moindre que $-\alpha$ en valeur absolue.

La formule (b) se déduit de (a) si l'on identifie $F\left\{\frac{\alpha,\, \beta,\, \epsilon-\delta}{\alpha+\beta-\gamma+1,\, \epsilon}\right\}$ avec $F\left\{\frac{\alpha',\, \beta',\, \delta'}{(\gamma',\, \epsilon'}\right\}$ en posant $\alpha=\alpha'$, $\beta=\beta'$, $\epsilon-\delta=\delta'$, $\alpha+\beta-\gamma+1=\epsilon'$, $\epsilon=\gamma'$; et que l'on applique la formule (a) aux lettres α', β', &c.

La formule (d) se deduit de (a) en posant

$$\epsilon-\delta=\alpha', \quad \beta=\delta', \quad \alpha=\beta',$$
$$\epsilon=\epsilon', \quad \alpha+\beta-\gamma+1=\gamma',$$

appliquant la formule (a) à $F\,\frac{\alpha',\, \beta',\, \delta'}{\gamma',\, \epsilon'}$, et transformant le facteur en dehors de F.

Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel. By G. Dickie, *M.D., Professor of Natural History, Queen's College, Belfast.*

The entrance to Strangford Lough is less than two miles in breadth; it gradually becomes narrower, forming a channel half a mile broad with a length of about three miles. The tidal current in this channel is estimated as having a velocity of nine miles per hour; as a consequence of such peculiarities, we find near Portaferry a depth of twenty-nine to thirty-five fathoms in the centre of the channel, and a gradual slope upwards from mid-channel to both shores. The bottom, in the deepest part, consists of rock with large and small stones interspersed; near the shore we find a mixture of small stones and gravel, and in the small bays sand or mud, or both intermixed.

The wider expansion of the Lough itself presents very much the same characteristics of bottom, with this difference, that the proportion of hard material is very much less, a large part consisting of mud. These peculiarities give rise to corresponding differences in the distribution of animal life, as the following facts testify:—

The fauna of parts of Strangford Lough has been examined by the late

Mr. Thompson and Mr. Hyndman, during excursions in 1832, 1846, and 1851. Some of the results of these dredgings, found among the papers of Mr. Thompson, will be given separately; the exact places dredged by these gentlemen are not in every case recorded.

About the middle of June of the present year (1857) I began the examination of the Lough; fortunately the weather was so favourable that during fifteen days' stay at Portaferry, twelve dredging excursions were made, each occupying five to eight hours. At the end of the first week I was joined by E. Waller, Esq., and received valuable aid from him in recording the lists of species.

It may be necessary to state that species designated as *common* or *very common* are those of which a considerable number of specimens were brought up at every haul of the dredge; of those called *rare*, not more than four or five were procured, either at one haul or as the result of several trials; the species marked *very rare*, are those of which not more than four or five specimens (generally not so many) were found among the entire products of all the excursions: as examples, may be mentioned *Chemnitzia scalaris* and *Terebratula caput-serpentis*.

These symbols have been used for brevity's sake :—

Very common	**	Very rare	‡
Common	*	Living	*l*
Rare	†	Dead	*d*

Strangford Lough, Castle Ward Bay; a quarter of a mile from the shore, depth seven to twenty fathoms; three and a half miles from the sea; bottom mud, small stones, gravel.

Tunicata.

Aplidium fallax * | *Clavellina lepadiformis* † | *Molgula tubulosa* *

Lamellibranchiata.

Pholadidæ.	Pholas candida	†	*d.*	*Cyprinidæ.*	Astarte triangularis	‡	*l.*
Gastrochænidæ.	Saxicava arctica	†	*l.*	*Cardiadæ.*	Cardium echinatum	*	*d.*
	—— rugosa	*	*l.*		—— edule	*	*d.*
Myadæ.	Mya truncata	†	*d.*		—— nodosum	*	*l.*
Corbulidæ.	Corbula nucleus	*	*l.*		—— fasciatum	‡	*d.*
Anatinidæ.	Thracia phaseolina	†	*d.*		—— pygmæum	†	*l.*
Solenidæ.	Solen ensis	*	*d.*		—— Suecicum	‡	*d.*
	—— pellucidus	†	*l.*	*Lucinidæ.*	Lucina borealis	*	*l.*
Solecurtidæ.	Solecurtus coarctatus	‡	*d.*		—— flexuosa	†	*d.*
Tellinidæ.	Psammobia Ferroensis	*	*d.*	*Kelliadæ.*	Kellia suborbicularis	†	*l.*
	—— tellinella	†	*l.*	*Mytilidæ.*	Modiola modiolus	*	*l.*
	Syndosmya alba	†	*l.*		—— phaseolina?	†	*l.*
	—— prismatica	‡	*l.*		Mytilus edulis	*	*l.*
Mactridæ.	Mactra elliptica	†	*l.*	*Arcadæ.*	Nucula nucleus	*	*l.*
Veneridæ.	Tapes virginea	*	*l.*		—— nitida	‡	*l.*
	—— pullastra	†	*l.*		Leda caudata	‡	*l.*
	—— aurea	†	*d.*	*Ostreadæ.*	Lima Loscombii	†	*d.*
	Venus casina	†	*l.*		Pecten striatus	‡	*d.*
	—— fasciata	*	*l.*		—— maximus	*	*d.*
	—— ovata	**	*l.*		—— opercularis	*	*l.*
	—— striatula	‡	*l.*		—— tigrinus	†	*d.*
	—— striatula	**	*d.*		Ostrea edulis	†	*d.*
Cyprinidæ.	Cyprina Islandica	†	*l.*		Anomia ephippium	*	*l.*
	Astarte sulcata	†	*l.*		—— striata	†	*d.*

Gasteropoda.

Chitonidæ.	Chiton asellus	*	*l.*
	—— fascicularis	‡	*l.*
	—— lævis	‡	*l.*
	—— ruber	†	*l.*
Patellidæ.	Patella pellucida	*	*l.*
	Acmæa virginea	*	*l.*
	—— testudinalis	†	*d.*
Dentaliadæ.	Dentalium entalis	*	*l.*
Calyptræidæ.	Pileopsis Hungaricus	†	*d.*
Fissurellidæ.	Fissurella reticulata	†	*d.*
	Emarginula reticulata	*	*d.*
Trochidæ.	Trochus cinerarius	**	*l.*
	—— magus	*	*l.*
	—— millegranus	†	*l.*
	—— Montagui	†	*d.*
	—— tumidus	*	*l.*
	—— zizyphinus	**	*l.*
	—— *var.* Lyonsii	†	*l.*
	Phasianella pullus	*	*l.*
Littorinidæ.	Lacuna crassior	‡	*d.*
	—— vincta	**	*l.*
	Rissoa Beanii	*	*d.*
	—— costata	†	*d.*
	—— crenulata	†	*d.*
	—— labiosa	*	*d.*
	—— rufilabrum	*	*d.*
Littorinidæ.	Rissoa striata	*	*d.*
Turritellidæ.	Turritella communis	*	*l.*
Cerithiadæ.	Aporrhais pes-pelecani	*	*l.*
	Cerithium reticulatum	*	*d.*
Pyramidellidæ.	Eulima bilineata	‡	*l.*
	—— polita	‡	*d.*
	Chemnitzia scalaris	‡	*d.*
	—— elegantissima	‡	*d.*
	—— indistincta	‡	*d.*
Naticidæ.	Natica nitida	*	*l.*
	—— sordida	‡	*d.*
Cypræadæ.	Cypræa Europæa	**	*d.*
Conidæ.	Mangelia turricula	†	*d.*
	—— rufa	†	*d.*
	—— septangularis	†	*l.*
	—— linearis	†	*d.*
Buccinidæ.	Nassa incrassata	*	*d.*
	Buccinum undatum	†	*l.*
	Fusus antiquus	†	*l.*
	Trophon clathratus	‡	*d.*
	—— muricatus	*	*d.*
	Murex erinaceus	†	*d.*
Bullidæ.	Cylichna cylindracea	†	*d.*
	—— obtusa	‡	*d.*
	Tornatella fasciata	‡	*d.*

The dead shells so abundant in this locality were chiefly *Tapes pullastra*, *T. virginea*, *Cytherea lincta*, *Venus ovata*, *V. striatula*, *Cardium nodosum*, *Corbula nucleus and Nucula nucleus*.

Wellstream Bay, west of Chapel Island; five miles from the sea; half a mile from the shore; chiefly mud; fifteen fathoms.

Lamellibranchiata.

Myadæ.	Mya arenaria	†	*d.*
Corbulidæ.	Corbula nucleus	*	*l.*
Anatinidæ.	Thracia phaseolina	†	*d.*
	—— convexa	†	*d.*
Solenidæ.	Solen pellucidus	†	*l.*
Solecurtidæ.	Solecurtus coarctatus	†	*d.*
Tellinidæ.	Psammobia Ferroensis	*	*d.*
	Syndosmya intermedia	†	*l.*
Veneridæ.	Tapes virginea	†	*l.*
	Venus ovata	†	*l.*
Veneridæ.	Artemis lincta	*	*l.*
	—— exoleta	†	*d.*
Cyprinidæ.	Astarte sulcata	†	*l.*
	Cyprina Islandica	†	*d.*
Cardiadæ.	Cardium echinatum	†	*d.*
	—— nodosum	†	*l.*
Lucinidæ.	Lucina borealis	†	*l.*
Arcadæ.	Nucula nucleus	*	*l.*
	—— nitida	†	*l.*

Gasteropoda.

Chitonidæ.	Chiton asellus	*	*l.*
Patellidæ.	Patella pellucida	†	*l.*
Dentaliadæ.	Dentalium entalis	†	*d.*
Trochidæ.	Trochus zizyphinus	†	*d.*
	—— tumidus	†	*l.*
Trochidæ.	Trochus Montagui	†	*l.*
Turritellidæ.	Turritella communis	†	*l.*
Naticidæ.	Natica nitida	†	*l.*
Muricidæ.	Trophon muricatus	†	*d.*

Upper part of Wellstream Bay, six miles from the sea; a mile from the shore; mud chiefly; four to eight fathoms.

Lamellibranchiata.

Gastrochænidæ.	Saxicava arctica	†	*l.*
Myadæ.	Mya truncata	‡	*d.*
Corbulidæ.	Corbula nucleus	*	*l.*
Pandoridæ.	Lyonsia Norvegica	‡	*d.*
Anatinidæ.	Thracia convexa	‡	*d.*
Solenidæ.	Solen pellucidus	†	*l.*
Solecurtidæ.	Solecurtus coarctatus	†	*d.*
Tellinidæ.	Tellina donacina	†	*d.*
	Psammobia Ferroensis	†	*d.*
Veneridæ.	Tapes virginea	*	*d.*

LAMELLIBRANCHIATA (*continued*).

Veneridæ. Venus striatula ...... * d.
—— ovata .... * l.
—— fasciata .... * d.
Artemis lincta ...... * d.
—— exoleta .... † d.
Cyprinidæ. Cyprina Islandica ... † d.
Isocardia cor .... ‡ d.
Cardiadæ. Cardium echinatum . † d.
Lucinidæ. Lucina flexuosa...... † d.
Mytilidæ. Modiola modiolus ... * d.
Modiola phaseolina . † l.
—— marmorata ... † l.
Arcadæ. Nucula nitida......... ‡ l.
—— nucleus .... * d.
Ostreadæ. Lima subauriculata .. ‡ d.
—— Loscombii...... ‡ d.
Ostrea edulis .... † d.
Anomia ephippium... * l.

GASTEROPODA.

Chitonidæ. Chiton asellus ...... * l.
Patellidæ. Acmæa virginea...... * l.
Dentaliadæ. Dentalium entalis ... * d.
Fissurellidæ. Emarginula reticulata * d.
Trochidæ. Trochus cinerarius... * l.
—— umbilicatus ... † d.
—— tumidus......... * l.
—— millegranus ... † d.
Trochidæ. Trochus zizyphinus . † l.
—— var. Lyonsii ... † l.
Turritellidæ. Turritella communis * d.
Cerithiadæ. Aporrhais pes-pelecani................. * l.
Naticidæ. Natica nitida .... † l.
Muricidæ. Buccinum undatum . † l.
Cypræadæ. Cypræa Europæa ... † d.

Bay opposite Killileagh; six miles from the sea; half a mile from the land; mud; six fathoms.

Myadæ. Mya truncata......... † d.
Corbulidæ. Corbula nucleus ... * l.
Solecurtidæ. Solecurtus coarctatus † d.
Tellinidæ. Psammobia Ferroensis * d.
Syndosmya alba...... † l.
Veneridæ. Venus casina .... † d.
Mytilidæ. Modiola modiolus ... * l.
Arcadæ. Nucula nucleus ...... * l.
Ostreadæ. Pecten opercularis... * d.
Anomia ephippium... * d.

GASTEROPODA.

Chitonidæ. Chiton asellus ...... † l.
Trochidæ. Trochus cinerarius... * l.
Turritellidæ. Turritella communis * d.

Near the centre of Strangford Lough, two to two and a half miles from either shore (in a line between Kircubbin and Killinchy); seven miles from the sea; chiefly mud; depth fifteen to twenty-five fathoms.

LAMELLIBRANCHIATA.

Solecurtidæ. Solecurtus coarctatus † d.
Pandoridæ. Lyonsia Norvegica . ‡ l.
Anatinidæ. Thracia convexa...... † d.
Corbulidæ. Corbula nucleus...... * l.
Veneridæ. Tapes virginea ...... * l.
Venus casina .... † d.
—— ovata ....** l.
—— striolata......... † l.
Cyprinidæ. Cyprina Islandica ... * l.
Astarte sulcata ...... * l.
Lucinidæ. Lucina borealis ...... † l.
—— flexuosa......... † d.
Kelliadæ. Kellia suborbicularis ‡ l.
Mytilidæ. Modiola modiolus ... * l.
Arcadæ. Nucula nucleus ...... * l.
—— nitida............ † l.
Ostreadæ. Pecten maximus ... † l.
—— striatus .... ‡ d.
—— opercularis......** l.
—— pusio .... * l.
—— varius............ * l.
Anomia ephippium... * l.
—— striata............ † l.
Ostrea edulis .... * l.

GASTEROPODA.

Patellidæ. Acmæa virginea...... * l.
Fissurellidæ. Fissurella reticulata . † l.
Emarginula reticulata † d.
Trochidæ. Trochus millegranus . † l.
—— zizyphinus...... † l.
—— cinerarius ...... * l.
—— tumidus......... * l.
Turritellidæ. Turritella communis * l.
Naticidæ. Natica sordida ...... ‡ d.
—— monilifera ...... † d.
Muricidæ. Nassa incrassata...... † d.
Buccinum undatum . * l.
Trophon muricatus... † d.
Bullidæ. Akera bullata .... † l.

The broken shells in this locality were chiefly *Venus ovata*, *Tapes virginea*, *Pecten opercularis*, *Modiola vulgaris*, and *Ostrea edulis*.

Bay to the north of Gun Island, in the Irish Channel, at south entrance of Strangford Lough; a mile from the shore; mud and sand; seven fathoms.

LAMELLIBRANCHIATA.

Tellinidæ.	Tellina fabula .... * *l.*	*Cardiadæ.*	Cardium nodosum... * *l.*
Veneridæ.	Venus striolata ...... * *d.*		

GASTEROPODA.

Fissurellidæ.	Fissurella reticulata . † *d.*	*Naticidæ.*	Natica nitida .... * *l.*
Trochidæ.	Trochus cinerarius... * *d.*	*Muricidæ.*	Nassa incrassata...... * *d.*
	—— tumidus.......... * *d.*		

In the open channel opposite to the entrance of Strangford Lough, the results of dredging indicated very regular distribution of materials throughout a distance of seven miles from the bar.

1. From the bar to one mile—more or less—large stones with a mixture of fragments about the size of the fist.
2. Two miles—more or less—from the bar, gravel, small stones, and shell sand.
3. Three miles—more or less—from the bar, gravel with dead and living mollusca, and fine debris of shells.
4. Four to five miles from the bar, sand and mud, with a smaller proportion of dead and living mollusca.
5. Six miles—more or less—from the bar, fine mud and sand.
6. Seven miles from the bar—more or less—fine black tenacious mud, with one living bivalve (*Syndosmya intermedia*), and *Brissus lyrifer.*

It need scarcely be stated, that the powerful currents which issue from the narrow opening of the Lough, in some measure account for these peculiarities, the lightest materials being carried farthest and deposited at a distance from the bar.

Mollusca of First Zone, 12 fathoms.

Chiton ruber, † *l.* | Chiton asellus, * *l.* | Acmæa virginea, * *l.*

Mollusca of Second and Third Zones, 12 to 15 fathoms.

LAMELLIBRANCHIATA.

Gastrochænidæ.	Saxicava rugosa ... * *l.*	*Cyprinidæ.*	Cyprina Islandica ... † *l.*
	—— arctica .... † *l.*		Circe minima......... ‡ *l.*
Myadæ.	Mya truncata.......... † *d.*		Astarte sulcata ...... † *d.*
Corbulidæ.	Corbula nucleus...... † *d.*		—— triangularis ... ‡ *l.*
Pandoridæ.	Pandora obtusa ...... ‡ *d.*	*Cardiadæ.*	Cardium nodosum... * *l.*
Anatinidæ.	Thracia phaseolina... † *d.*		—— pygmæum ...... † *d.*
Solenidæ.	Solen siliqua .... † *d.*		—— Norvegicum ... ‡ *d.*
	—— ensis .... † *d.*	*Lucinidæ.*	Lucina borealis ...... † *l.*
Solecurtidæ.	Solecurtus coarctatus ‡ *d.*	*Kelliadæ.*	Kellia suborbicularis ‡ *l.*
	—— candidus ...... ‡ *d.*		Montacuta substriata ‡ *l.*
Tellinidæ.	Tellina crassa......... † *d.*	*Arcadæ.*	Nucula nucleus ...... * *d.*
	—— fabula .... † *l.*		Pectunculus glycymeris ** *l.*
	Psammobia Ferroensis † *d.*	*Mytilidæ.*	Modiola modiolus ... * *l.*
	—— tellinella ...... * *l.*		—— phaseolina? ... † *l.*
	Syndosmya prismatica ‡ *l.*	*Ostreadæ.*	Lima Loscombii...... ‡ *l.*
Mactridæ.	Mactra elliptica ...... * *l.*		Pecten similis......... ‡ *d.*
	Lutraria elliptica ... * *l.*		—— varius............ † *d.*
Veneridæ.	Tapes virginea ...... * *l.*		—— opercularis...... * *d.*
	Venus casina .... † *d.*		—— maximus ...... † *d.*
	—— fasciata .... † *l.*		—— tigrinus .... * *l.*
	—— striatula ...... † *d.*		Ostrea edulis .... † *l.*
	—— ovata.............. * *d.*		Anomia striata ...... † *l.*
	Artemis exoleta ...... † *d.*		—— ephippium...... * *l.*
	—— lincta............ † *l.*		—— patelliformis ... † *l.*

BRACHIOPODA.

Terebratulidæ.	Terebratula caput-serpentis, ‡ *l.*	*Craniadæ.*	Crania anomala... ‡ *l.*

Gasteropoda.

Chitonidæ.	Chiton asellus ...... * *l.*	*Pyramidellidæ.*	Eulima distorta (var.
	—— ruber .... † *l.*		gracilis) .... ‡ *d.*
Patellidæ.	Patella pellucida...... † *d.*		Chemnitzia elegantissima ‡ *d.*
	Acmæa virginea...... † *l.*		Odostomia unidentata ... ‡ *d.*
Dentaliadæ.	Dentalium entalis ... * *d.*		—— spiralis .... † *d.*
Calyptræidæ.	Pileopsis Hungaricus ‡ *d.*	*Naticidæ.*	Natica monilifera ... † *d.*
Fissurellidæ.	Fissurella reticulata . ‡ *d.*		—— nitida........... * *d.*
	Emarginula reticulata † *l.*	*Velutinidæ.*	Lamellaria perspicua ‡ *d.*
Trochidæ.	Trochus zizyphinus . † *l.*	*Cancellariadæ.*	Trichotropis borealis ‡ *d.*
	—— Montagui ...... * *l.*	*Muricidæ.*	Nassa incrassata...... * *d.*
	—— cinerarius ......** *l.*		Buccinum undatum . * *l.*
	—— tumidus......... * *d.*		Fusus antiquus ...... † *l.*
Littorinidæ.	Rissoa labiosa ...... * *d.*		Trophon muricatus . † *d.*
	—— striata .... * *d.*		—— clathratus ...... † *d.*
	—— crenulata ...... ‡ *d.*		—— Barvicensis ... ‡ *d.*
Cerithiadæ.	Cerithium adversum ‡ *d.*	*Conidæ.*	Mangelia linearis ... ‡ *d.*
	—— reticulatum ... * *d.*		—— costata .... ‡ *d.*
	Eulima bilineata...... † *d.*		—— purpurea ...... ‡ *d.*
Pyramidellidæ.	—— polita .... ‡ *l.*		—— rufa .... † *d.*

Mollusca of Fourth Zone, 18 *to* 20 *fathoms.*

Lamellibranchiata.

Corbulidæ.	Corbula nucleus...... † *l.*	*Cyprinidæ.*	Circe minima......... ‡ *d.*
Pandoridæ.	Pandora obtusa ...... ‡ *l.*		Cyprina Islandica ... * *l.*
Solenidæ.	Solen pellucidus...... † *l.*	*Cardiadæ.*	Cardium echinatum . † *d.*
Tellinidæ.	Psammobia tellinella † *d.*		—— nodosum ...... ‡ *l.*
	—— Ferroensis ...... † *d.*	*Mytilidæ.*	Modiola modiolus ... * *d.*
Mactridæ.	Mactra elliptica...... * *d.*		Crenella decussata . . ‡ *l.*
Veneridæ.	Tapes virginea ...... † *d.*	*Arcadæ.*	Pectunculus glycimeris * *d.*
	Venus casina .... † *l.*	*Ostreadæ.*	Pecten opercularis... * *d.*
	—— fasciata .... † *d.*		—— tigrinus .... † *l.*
	—— ovata .... * *d.*		—— varius............ † *d.*

Gasteropoda.

Dentaliadæ.	Dentalium entalis ... * *d.*	*Naticidæ.*	Natica nitida .... † *l.*
Fissurellidæ.	Emarginula reticulata † *d.*		—— sordida .... ‡ *d.*
Trochidæ.	Trochus cinerarius... * *d.*	*Muricidæ.*	Nassa incrassata ... * *d.*
	—— Montagui ...... * *d.*		Fusus antiquus ...... † *l.*
	—— tumidus......... * *l.*		Trophon muricatus . † *d.*
Littorinidæ.	Rissoa striata......... * *d.*	*Conidæ.*	Mangelia attenuata . ‡ *d.*
Pyramidellidæ.	Chemnitzia indistincta ‡ *d.*		

Mollusca of Fifth Zone, 25 *fathoms.*

Solenidæ.	Solen pellucidus ... * *l.*	*Dentaliadæ.*	Dentalium entalis ... * *d.*
Tellinidæ.	Syndosmya intermedia * *l.*	*Turritellidæ.*	Turritella communis * *l.*
Veneridæ.	Venus ovata .... † *l.*	*Naticidæ.*	Natica nitida .... † *l.*

Mollusca of Sixth Zone, 26 *fathoms.*

Tellinidæ.	Syndosmya intermedia * *l.*	*Conidæ.*	Mangelia linearis ... ‡ *d.*

Along with these a single living specimen of the rare *Brissus lyrifer* was procured.

In Strangford Lough 103 species (dead or living) were dredged: 58 Bivalves and 45 Univalves. The locality which produced the largest number is near the junction of the narrow channel with the wider part of the Lough itself, viz. Castle Ward Bay; the general result being—

Lamellibranchiata.	Living 29 species Dead 18 ,,	=47
Gasteropoda	Living 22 ,, Dead 31 ,,	=53
		100 species.

The next locality worth mentioning is Wellstream Bay, about two miles within the wider part of the Lough, or that distance from the upper end of the narrow channel, and five to six miles from the sea. Contrasted with the former locality, the number of species is reduced to one-half, viz.

Lamellibranchiata.	Living	10	species	=32
	Dead	22	,,	
Gasteropoda	Living	10	,,	=18
	Dead	8	,,	
				50 species.

In the widest part of the Lough, near its centre, and farther from the sea than the previous locality, we find a still greater reduction in the number:—

Lamellibranchiata.	Living	21	species	=26
	Dead	5	,,	
Gasteropoda.	Living	8	,,	=14
	Dead	6	,,	
				40 species*.

In the open Irish Channel, outside the Lough, 96 species were dredged, in the following proportions:—

Lamellibranchiata.	Living	31	species	=55
	Dead	24	,,	
Gasteropoda	Living	11	,,	=41
	Dead	30	,,	
				96 species.

It may be worthy of notice, that the dead shells found in the outside Channel, and those dredged in the Lough, presented an aspect so different, that if the two were mixed together, I could easily point out those found in the one or the other locality. Those dredged at sea were peculiarly fresh in external appearance, and generally retained their original consistence, and in many cases their colour; whereas those found in the Lough had almost universally lost their colour, and in many instances were so decayed that they could be easily crushed by the fingers.

On taking a general view of the Molluscan fauna of Strangford and that of the Irish Channel opposite its entrance, we remark the absence of species belonging to the Lusitanian and South British types†, and the general occurrence of those of the European type, with a large proportion of those called Celtic. Some of those considered as more peculiarly British (British type), are also not uncommon, as *Trochus Montagui*, *T. millegranus*, *Pecten tigrinus*. Those of the Atlantic type are generally rare, the only species found in abundance being *Cerithium reticulatum*, *Mangelia gracilis*, and *Psammobia tellinella*; others being rare, as *Cerithium adversum*, *Circe minima*, *Fissurella reticulata*, *Natica sordida*, *Terebratula caput-serpentis*, &c. Those of the Boreal type are represented by *Cyprina Islandica*, which is not uncommon, and by a few others which are rare, as *Cardium suecicum*, *Crania anomala*, *Leda caudata*, *Syndosmya intermedia*, and *Trichotropis borealis*.

The general conclusion is, that the Mollusca recorded here belong mainly to the European and Celtic types, with a moderate proportion of species belonging to the Atlantic type, and a very few Boreal forms.

* Species procured by the dredge only are recorded here; littoral species, common everywhere, are not included.

† Forbes and Hanley's British Mollusca, vol. i. Introduction.

ECHINODERMATA *of Strangford and corresponding part of the Irish Channel.*

Comatula rosacea. Abundant in various parts of the Lough in 10 to 15 fathoms. Rare outside in 20 fathoms.
Ophiura texturata. Plentiful in Lough and Channel, in 10 to 20 fathoms.
——— *albida.* Less common than the last, and along with it.
Ophiocoma neglecta. In Channel, 25 fathoms, rare.
——— *granulata.* Velvety black. Common in different parts of the Lough, 10 to 20 fathoms. Rare in the Channel.
——— *bellis.* Abundant in 20 fathoms, chiefly in upper part of the Lough, between Kircubbin and Killinchy. Also in the Channel, but rare.
——— *rosula.* Very common in all parts of the Lough; less so in the Channel.
——— *filiformis.* In the Channel, six miles off; rare.
Uraster glacialis. Occasionally inside and outside the Lough, at different depths.
——— *rubens.* Occasionally in the Lough.
——— *hispida.* Occasionally in the Lough and Channel.
Solaster endeca. In upper part of the Lough, between Kircubbin and Killinchy, not unfrequent.
——— *papposa.* In different parts of the Lough, but rare.
Palmipes membranaceus. In upper part of the Lough, between Kircubbin and Ardmillan; rare.
Echinus sphæra. In the greatest profusion at low-water mark in the lower part of the Lough, also in 10 to 25 fathoms everywhere.
——— *miliaris.* Abundant in the Lough and in the Channel, 10 to 25 fathoms.
Echinocyamus pusillus. In the Lough and outside, in 15 to 25 fathoms, rather rare.
Spatangus purpureus. Occasionally, between Ardmillan and Kircubbin, 25 fathoms. Also outside the Lough, but rare.
Brissus lyrifer. A single specimen (very fine), in mud, seven miles outside Strangford Bar, 25 fathoms.
Amphidotus cordatus. Not uncommon in the Lough, in 10 to 20 fathoms; rare in the Channel.
——— *roseus.* Off Strangford Bar, rare, 20 fathoms.
Cucumaria fusiformis. In the Lough, 15 fathoms, very rare.
Ocnus brunneus. In the Lough, 10 to 15 fathoms; abundant.

In addition to these, the following are recorded in 'Notes of Dredging,' by the late Mr. Thompson and Mr. Hyndman:—

Cribella oculata.	A few, 15 to 20 fathoms.
Thyone papillosa.	In 15 to 20 fathoms.
Cucumaria hyalina.	In 15 to 20 fathoms.
Syrinx Harveii.	In 15 to 20 fathoms.

TUNICATA.

The following list of Strangford species is compiled from the results of dredging by the late Mr. Thompson and Mr. Hyndman; most of them were also dredged by myself in June last (1857):—

Ascidia mentula. Abundant, 4–6 fathoms.
—— *venosa.* Several, ditto.
—— *prunum.* With the last.
—— *parallelogramma.* On shells.
—— *scabra.* Several, 4–6 fathoms.
—— *canina.* Ditto, ditto.
—— *orbicularis.* Rare, ditto.
—— *echinata.* Very rare.
—— *intestinalis.* Not uncommon.
—— *vitrea.* Very rare.
Molgula tubulosa. Not uncommon.
Cynthia microcosmus. Common, 4–6 fathoms.
—— *claudicans.* Rare, ditto.
—— *mora.* Rare, ditto.
—— *rustica.* Common, ditto.
Clavellina lepadiformis. Not uncommon.
Botryllus Schlosseri. Rare.
—— *polycyclus.* Common.
Leptoclinum aureum. Occasionally.
Aplidium fallax. Common.

Crustacea.

Dredged by Mr. Thompson in September 1851, in 4 to 6 fathoms, near Ringdufferin and Ringhaddy Islands; most of these were also got in June 1857:—

Stenorhynchus phalangium.
Inachus Dorsettensis.
—— *dorynchus.*
Hyas araneus.
Eurynome aspera.
Portunus pusillus.
—— *arcuatus.*
Pagurus Bernhardus.
Porcellana longicornis.
Galathea squamifera.
Hippolyte varians.

Sponges of Strangford Lough.

These were mostly all got in one locality, upon oyster and scallop beds, in about 20 fathoms, near the centre of the expanded part of the Lough, between Killinchy and Kircubbin. These were long since dredged by Messrs. Thompson and Hyndman, and nearly all were found in 1857:—

Tethya lyncurium.
Halichondria hispida.
—— *fucorum.*
—— *sanguinea.*
—— *macularis.*
Halichondria hirsuta.
—— *suberea.*
—— *mammillaris.*
—— *carnosa.*
Cliona chelata.
Grantia lacunosa.
—— *fistulosa.*
Dysidea fragilis.

Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth. By Charles Atherton, *Chief Engineer of Her Majesty's Dockyard, Woolwich.*

At the Cheltenham Meeting of the British Association in August 1856, I had the honour to present a paper on "Mercantile Steam Transport Economy." The principal objects of that paper were, in the first place, to expose the difficulty which attends all investigation and even all discussion on maritime affairs, in consequence of the technical terms in which shipping, especially steam shipping, is spoken of, and officially registered as respects the size or magnitude of vessels and machinery, having no definite meaning expressive of the capability of ships for carrying weight of cargo, or the capability of the machinery for the production of working power; and in the second place, after getting the better of the foregoing difficulty by rejecting the records of tonnage and nominal horse-power as being indefinite, and basing my calculations on load displacement, as expressing the actual magnitude and weight of the mass propelled through the water, and assigning an arbitrary but definite amount of working power based on indicator measurement to the term horse-power, and availing myself of maritime statistics already published as to the actual performances of vessels, and of the received laws which are recognized as expressing the mutual relations of displacement, power, and speed under definite conditions of practical application, I was enabled to demonstrate approximately the proportional increased rate of pecuniary cost which attends an increased rate of speed at which cargo per ton weight may be conveyed by steam-ships of any definite size and type, according to the length of passage and speed that may be required: for example, assuming a passage of 3250 nautical miles to be performed by a vessel of 2500 tons load displacement, and of which the coefficients of dynamic duty were assumed to be known and equal, and of a comparatively high order, the vessels respectively being fitted for speeds of 8, 10, and 12 knots per hour, it was shown that the cost of transport per ton weight at the speed of 12 knots per hour would be about 50 per cent. above the cost that would be incurred by a speed of 10 knots, and about 100 per cent., or double the cost incurred by a speed of

8 knots; and if the vessels be of a certain comparatively inferior type of build, as indicated by a lower coefficient, but still of such type as is commonly employed, the rate of freight per ton weight of cargo conveyed at the 12 knots' speed on the passage referred to, was found to be about double the rate if conveyed at the speed of 10 knots per hour, and about three times the rate incurred by a speed of 8 knots an hour.

Applying this estimated difference of cost incurred by difference of type to the aggregate trade of the country, as shown by the statistical returns of the Customs' House, it was suggested that the pecuniary interest of the great paymaster "the public," is involved to the extent of millions per annum, simply by the difference of type of build and condition of the ships and engines, and administrative management by which the foreign trade of the country, as respects transport, may be prosecuted. These points of my former paper are now referred to by way of introduction to the following paper, in which it is purposed to continue the subject-matter of my former dissertation, by showing the extent to which the weight-carrying capability of ships of given tonnage, whether rated by the gross register tonnage (new measure), under the Merchant Shipping Act of 1854, or by the tonnage builders' measure O.M. (also commonly called "burden," and still generally in use, though legally superseded in 1835), is dependent on the relative proportions of length, breadth, and depth to which ships may be constructed; and it is submitted for the consideration of the Association that this point of inquiry comes to be of special importance, seeing that the tendency of the present times to build vessels of great magnitude as respects length and breadth, whilst the load-draught is restricted by local circumstances within the definite limit of the minimum depth of water of the ports to be frequented, has a direct tendency to involve a condition of things as respects proportions of build adverse to public interests, for the public will have to bear the brunt of freight charges proportional to the cost expenses that may be incurred in the general administration of shipping affairs. We may just as well assert that the public have no interest in the efficiency of our army and navy, as that it has no interest in the efficiency of our commercial shipping. Rates of freight (excepting on occasions of national emergency) must be ruled in the aggregate by the general average cost at which the general service of mercantile transport is actually performed, whether it be well or ill performed; and the general introduction of proportions of build which can only perform their service at high rates of freight above the prime cost rates which would duly remunerate vessels of superior type, involves pecuniary considerations that may well form the subject of special statistical inquiry to be prosecuted at the instance of the British Association. The application of statistical science in connexion with shipping as a means of inquiry into the principles of Mercantile Steam Transport Economy, is, I may say, a new subject of inquiry, to which the British Association, and, I must add, the Society for the Promotion of Arts, Manufactures, and Commerce, have given public vitality. The question of Maritime Transport Economy has a bearing on public interests analogous to the operation of the rail and the telegraph.

A further object of this paper is, that by means of the following Table (A), which has been prepared to show the mutual relations which subsist in ships of given variations of build between Tonnage Builders' Measurement O.M., Gross Register Tonnage, Weight Tonnage, or the capability of ships to carry weight of cargo, and the corresponding displacement when ships are loaded down to a determinate load line; and Table B, showing the mutual relations of displacement, power, and speed, we may thus have the means of connect-

ing (that is, within the limitations of the variations of build referred to in Tables A and B), through the intermediate element "displacement," the two Tables A and B thus establishing the mutual relations within the limits aforesaid, between builders' tonnage, gross register tonnage, and weight or cargo tonnage, with the power required to attain a given speed, thus enabling us to show the bearing of proportions of build as affecting mercantile steam transport economy.

In the first place, therefore, before entering on this exposition, and in consideration that persons generally, even amongst those who devote their time to popular and statistical studies, and to scientific pursuits, and even assume the responsibilities of legislation on shipping, are not familiar with the technical meaning of the terms "tonnage" and "burden," which are of such frequent recurrence in discussing the properties of shipping, as compared with the ordinary and unsophisticated meaning of those words, and are actually and unconsciously misled by those terms, when used technically in shipping sophistry, having a signification quite at variance with their ordinary meaning, I will endeavour to dispel this mystery by a few remarks in explanation of the terms "tonnage" and "burden," which, above all other terms, are most amenable to the foregoing singular imputation, namely, that their technical meaning is directly at variance with the ordinary signification of the said words: for example, ship's "tonnage" is not spelt with a U, "tunnage," and we all know that a "ton," as distinguished from "tun," popularly signifies 2240 lbs. weight, or 20 cwt., each cwt. being 112 lbs. The ordinary acceptation of the word "ton" implies a unit of weight, not of measure. Thence it is popularly inferred that the "tonnage" of a ship means the number of tons weight which constitute the proper load of a ship; but what is a ship's tonnage as implied in the terms "tonnage O.M.," "tons burden," "register tonnage"? It has nothing whatever to do with weight. By the old law, termed "builders' measurement O.M.," which, though legally superseded in 1835, is still practically in use, and constitutes to this day the rule which, even in the Government service, generally regulates the builder's contract price of shipping, the measurement of this tonnage is regulated by the length of the ship and its breadth only, taking no cognizance of depth. It has nothing whatever to do with the load-draught of water for which a ship may be constructed. Provided that the length and breadth of two ships be the same, the builders' tonnage O.M. will be the same, though the load-draught of one ship be 30 feet and of the other only 3. This same tonnage, builders' measure O.M., is also frequently called by the equally delusive term "burden," though, as above shown, it has nothing to do with burden: for example, in shipping advertisements we see daily that "tons burden" is a designation by which ships are commonly advertised. It is true that Parliament abolished that law of tonnage, builders' measurement O.M., or the so-called "burden," in 1835, but nevertheless the Government have continued to uphold the rule (builders' measurement) as the base of their ship-building contracts, and ships, as respects their comparative size, are still only known to the world generally by their so-called tonnage or tons burden, or builders' measurement O.M. No steps having been taken by the Government to discontinue and forbid the use and adoption of the old law of measurement, though repudiated by statute in 1835, it has continued to prevail, and merchants, following the example of the Government, make it the general base of building contracts to the present day.

It is therefore submitted for the consideration of the British Association, that the statute abolition of tonnage builders' measurement O.M., also called "burden," ought not to be permitted to lie dormant. It should be expressly

decreed that the said builders' measurement O.M. is not legally binding in any contract, either for the building, or freighting, or chartering of ships, and that the definition and measurement of "tonnage" shall be in accordance with the existing law, viz. the Merchant Shipping Act of 1854, subject to such amendments thereof and additions thereto as may be found necessary to render the Act complete for all the purposes of shipping registration.

And now, what is tonnage registration under the new law—the Merchant Shipping Act of 1854? To begin with: vessels constructed previously to 1854 are permitted, at the option of their owners, to retain their former tonnage or be measured under the new law, and be registered accordingly, and the statistics or Parliamentary returns of shipping do not show to what extent this privilege, of optionally withholding the former registration, has been acted upon; so that our present registration under the new law, the Act of 1854, is a mixed registration, and we do not know the ingredients thereof or their proportion; but the measurement under the new law of all ships built since May 1855, is an internal measurement, no notice whatever being taken of external measurement, or of the light draught line or constructor's load line, or any limitation thereof assigned by reference to "freeboard;" and consequently tonnage under the new law, the Act of 1854, does not give the weight-carrying capability of ships, nor any comparison thereof, if of different types of form, and of different build as respects the weight of the materials employed; but if the law does not give the weight-carrying capability of the ship, the question is—what does it give? It gives an admissibly correct measurement of the internal capacity of ships, but calls this capacity "tonnage," giving a new signification to the word ton; for each 100 cubic feet of this internal space of the ship available for holding cargo is called a ton of tonnage. Tonnage is therefore a mere measurement of space, not of weight. Then, again, as regards cargo, even a ton of cargo is not always rated as 20 cwts. The freight of goods is charged either by measurement or by weight, and the same word "ton" is applied in all cases; 100 cubic feet constitute a ton of shipping; 40 cubic feet of some kinds of goods, and 50 feet of others, constitute a ton of measurement goods; and cargo is rated accordingly for freight, provided the said measure do not weigh a ton. 100 cubic feet of light goods may therefore be stowed in 1 ton of shipping, and be rated for freight at $2\frac{1}{2}$ tons; that is, a ship of 1000 tons register tonnage may be expected to stow 2500 tons of measurement cargo, or, better still, 1000 tons weight of heavy goods, and fill up with 2000 tons measurement of light cargo, and thus go to sea with this 3000 tons of freight, no limitation being assigned to draught. Such are the anomalies of tonnage, and yet we talk of statistics based on tonnage; and what is the consequence of this abuse of the word "ton"? Why, in times of war, our tonnage registration of shipping not only affords no reliable data, but actually deceives as to the capabilities of vessels for carrying ordnance and such like heavy military stores. Experience of the past three years has abundantly shown how great would be the advantage to the public if, in times of war and emergency, when there is no time for the readmeasurement of shipping, and when shipping must be chartered or purchased at any price, our registration of shipping were available, like a tabular ready-reckoner, for giving the Government a correct idea of the capability of every ship for conveying weight of cargo, in addition to the present registration of capacity for holding cargo, and consequently a comprehensive view of the value of ships for military transport service embracing both weight and roomage.

The statistical insufficiency of the present system of shipping registration as a record of the capability of ships, is shown by the following Table (A):—

TABLE A.—Showing approximately the extent to which the mutual relations of TONNAGE BUILDERS' MEASURE O.M., TONNAGE GROSS REGISTER NEW MEASURE under the Merchant Shipping Act of 1854, WEIGHT TONNAGE or Capability for carrying tons weight of Cargo, and LOAD DISPLACEMENT as regulated by some definite limit of Freeboard, are dependent on the proportions of Length, Breadth, and Depth that may be adopted in the construction of Ships of the same Nominal Tonnage.

CONSTRUCTOR'S DIMENSIONS.						ELEMENTS OF CONSTRUCTION.										MUTUAL RATIOS OF TONNAGE AND LOAD DISPLACEMENT.															
																TONNAGE. Bds' Measure O.M. taken at 100.				TONNAGE. Gross Register, taken at 100.				TONNAGE. Weight Tonnage, taken at 100.				LoadDisplacement, taken at 100.			
Designation of Vessels.	Length (L).	Breadth (B).	Load Draught (D), exclusive of keel.	Freeboard (F), taken at $\left(\frac{L}{40}+\frac{B}{12}\right)$.	Depth external (D+F).	Load Displacement taken at $\frac{6}{10}$ L B D.	Freeboard Buoyancy taken at $\frac{7}{10}$ L B F.	External Measurements (M), being the Load Displacement + Freeboard Buoyancy.	Light Displacement (m) ready for Cargo, taken at one-third M.	Weight Tonnage (W), being the difference between the Load and Light Displacements.	Ratio of Internal to External Measurements.	Register Tonnage (gross), at 100 feet internal measurement per ton (G R).	Builders' Tonnage (O.M.).	Ratio of Length to Breadth.	Ratio of Load Draught to Breadth.	Builders' Tonnage (O.M.).	Register Tonnage (Gross).	Weight Tonnage.	Load Displacement.	Register Tonnage (Gross).	Builders' Tonnage (O.M.).	Weight Tonnage.	Load Displacement.	Weight Tonnage.	Builders' Tonnage (O.M.).	Register Tonnage (Gross).	Load Displacement.	Load Displacement.	Builders' Tonnage (O.M.).	Register Tonnage (Gross).	Weight Tonnage.
	Feet.	Feet.	Feet.	Feet.	Feet.	Tons.	Tons.	Tons.	Tons.	Tons.		Tons.	Tons.			Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns	Tns
Ships of 1000 tons Bds' Measure O.M. A	152·40	38·10	25·40	6·35	31·75	2317	695	3012	1004	1313	·81	854	1000	4 to 1	·66 to 1	100	85	131	232	100	118	177	273	100	76	65	177	100	43	37	57
B	152·40	38·10	19·05	6·35	25·40	1738	695	2433	811	927	·80	681	1000	4	·50 to 1	100	68	93	174	100	147	136	256	100	107	73	187	100	57	39	53
C	152·40	38·10	12·70	6·35	19·05	1158	695	1853	618	540	·79	512	1000	4	·33 to 1	100	51	54	116	100	196	106	228	100	185	94	215	100	86	44	47
D	195·90	32·65	21·77	6·80	28·57	2188	820	3008	1003	1185	·79	832	1000	6	·66 to 1	100	83	119	219	100	120	143	264	100	84	70	184	100	46	38	54
E	195·90	32·65	16·33	6·80	23·13	1641	820	2461	820	821	·78	656	1000	6	·50 to 1	100	66	82	164	100	154	125	252	100	122	79	200	100	61	40	50
F	195·90	32·65	10·88	6·80	17·68	1093	820	1913	638	455	·77	516	1000	6	·33 to 1	100	52	46	109	100	196	88	214	100	217	111	237	100	91	47	42
G	235·20	29·40	19·60	7·35	26·95	2129	958	3087	1029	1100	·77	832	1000	8	·66 to 1	100	83	110	213	100	120	132	257	100	91	76	194	100	47	39	52
H	235·20	29·40	14·70	7·35	22·05	1597	958	2555	852	745	·76	680	1000	8	·50 to 1	100	68	75	160	100	147	110	235	100	133	91	213	100	63	43	46
I	235·20	29·40	9·80	7·35	17·15	1065	958	2023	674	391	·75	531	1000	8	·33 to 1	100	53	39	107	100	189	74	219	100	256	136	274	100	94	50	37
K	271·40	27·14	18·10	9·04	27·14	2285	1306	3591	1197	1088	·75	942	1000	10	·66 to 1	100	94	109	229	100	106	115	244	100	92	86	210	100	44	41	48
L	271·40	27·14	13·57	9·04	22·61	1713	1306	3019	1006	707	·74	782	1000	10	·50 to 1	100	78	71	171	100	128	91	219	100	128	110	241	100	58	45	41
M	271·40	27·14	9·05	9·04	18·09	1143	1306	2449	816	327	·73	626	1000	10	·33 to 1	100	63	33	114	100	159	52	181	100	303	191	345	100	87	55	29
X	540·0	90·0	30·0	21·00	51·00	25000	20412	45412	15137	9863	·77	12238	20939	6	·33 to 1	100	58	47	119	100	171	81	205	100	213	123	233	100	84	49	39
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

In this Table it will be observed that the twelve vessels, A, B, C, &c. to M, are all of the same builders' tonnage O.M., namely 1000 tons; that we have three vessels (A, B, C) whose length is four times the breadth of beam; three vessels (D, E, F) whose length is six times the breadth; three vessels (G, H, I) whose length is eight times the breadth; and three vessels (K, L, M) whose length is ten times the breadth; and that, in each set of three vessels, the load-draught of water is taken at two-thirds of the breadth, half the breadth, and one-third of the breadth; so that in this Table we have a gradation of proportions, the length varying from four times to ten times the breadth, and the load-draught varying from two-thirds to one-third of the breadth, which limits embrace nearly all the proportions of shipping in mercantile use. The arbitrary elements of construction on which the calculations (Table A) have been prosecuted, are explained in the various headings. It will be observed that the freeboard (column 5), or non-immersed depth above the load-draught line, has in each case been taken at one-fortieth of the length, plus one-twelfth of the breadth of beam. There is no recognized rule for the determination of this element. Constructors of shipping follow their own rules or their own caprice in determining freeboard, or the position of the construction load-line. The above combined proportions of length and breadth have been adopted, as giving a progression, which, it is believed, will meet the ordinary allowance of freeboard at which loaded ships of all sizes are sent to sea. The various elements of construction (columns 7 to 16) are believed to be closely approximate to ordinary practice; and the ratios of nominal tonnage to actual weight-carrying capability, shown in columns 17 to 20, are therefore approximately such as would result from the ordinary build of shipping.

Now, on comparing the ratios which result from the constructive proportions of the ships A, B, C, &c., M, we have the following results:—1st, it appears (see columns 17 to 20), that, taking builders' tonnage at 100, the ratio of register tonnage varies from 85 to 51 in ships (A, B, C) of which the length is four times the beam, and from 94 to 63 in ships (K, L, M) of which the length is ten times the beam; that is, taking the extreme cases embraced within the limits of this Table, a ship of type K will have a register tonnage of 94 tons for every 100 tons builders' measure; but a ship of type C will have only 51 tons register for each 100 tons builders' measure. It also appears (see columns 17 and 19), with reference to builders' tonnage O.M., taken at 100, that the capability for carrying weight fluctuates from 131 tons weight down to 33 tons weight per 100 tons of builders' measure O.M., or a ship of 1000 tons builders' tonnage of the type A will have four times the weight-carrying capability that is afforded by a ship of 1000 tons builders' tonnage of the type M.

With reference to register tonnage (gross), new measure, under the Act of 1854, taken at 100, it appears (see columns 21 and 23) that the capability for carrying weight varies from 177 tons down to 52 tons per 100 tons of register tonnage; or a ship of 1000 tons gross register tonnage of the type A will have nearly $3\frac{1}{2}$ times the weight-carrying capability that is afforded by a ship of 1000 tons gross register tonnage of the type M.

With reference to weight tonnage, or the capability of ships to carry weight, it appears (see columns 25, 26, 27) that, with the proportions of ship A, each 100 tons of weight-carrying capability will require a vessel of 76 tons builders' measure O.M., or 65 tons gross register tonnage; but with the proportions of ship M, each 100 tons of weight-carrying capability will require a vessel of 303 tons builders' measure O.M., or 191 tons gross register tonnage.

With reference to the mutual relation of the load displacement and weight tonnage, it appears (see columns 29 and 32) that with the proportions of ship A, each 100 tons of load displacement will give 57 tons of weight tonnage, but with the proportions of ship M, each 100 tons of load displacement will give only 29 tons of weight tonnage; that is, a ship of 1000 tons load displacement, on the type of ship A, will carry double the weight that would be carried by 1000 tons of displacement on the type of ship M.

It might possibly be objected that the foregoing variations, which have all been calculated with reference to ships of 1000 tons builders' measure O.M., are not applicable to vessels of a different magnitude; therefore, to test the validity or otherwise of this remark, the same constructive elements have been applied to a ship X of 20,939 tons builders' measure O.M., and 25,000 tons load displacement, the length of this ship X being six times the beam, and the load-draught one-third of the beam, this type or proportion being the same as that of ship F. On comparison of the ships X and F (see columns 29, 30, 31 and 32), it will be found that the ratios of builders' tonnage, register tonnage, weight tonnage, and load displacement, are closely similar throughout: for example, in ship F, each 100 tons load displacement gives 42 tons of weight tonnage, but in ship X each 100 tons of load displacement gives 39 tons of weight tonnage. Hence we may infer that the results of these calculations, showing the extent to which the weight-carrying capabilities of ships is irrespective of the nominal tonnage, whether it be builders' tonnage O.M., or gross register tonnage N.M., and is approximately dependent on the constructor's proportions of build, admit of general application to vessels of all sizes of the types referred to in Table A. Surely the above exposition is sufficient to establish the necessity of some legislative enactment under which builders' tonnage O.M., and register tonnage N.M., should not be permitted to co-exist as recognized measurements of the mercantile capabilities of shipping. Under existing circumstances, it is respectfully submitted for the consideration of the British Association, that a clause be introduced into the Merchant Shipping Act, that the only legal signification of the word "tonnage" shall be the measurement prescribed by the said Act, and that no other signification of that term shall be legally binding in commercial transactions. Also, that the capability of ships for carrying weight, as measured with reference to some determinate freeboard, be made an item of registration.

The ratios above set forth, as expressing the weight-carrying capability of ships, include the whole weight available for engines, boilers, coal, consumable stores, and cargo; so that, as applied to steam-ships, these ratios, as respects weight-tonnage for cargo chargeable for freight, assume a new phase of great importance as affecting mercantile steam transport economy; and, for the purpose of inquiring into the modification thus introduced, the following Table B has been calculated, showing the mutual relations of displacement, power, and speed, for vessels up to 25,000 tons load displacement, the speed varying from 6 knots up to 25 knots per hour.

The element "Load Displacement" being common to both Tables A and B, we have, by the aid of these Tables combined, the means of showing the mutual relations between builders' tonnage O.M., gross register tonnage N.M., weight-tonnage, load displacement, speed, and power of all vessels within the limits of the types or proportions of build referred to in Table A, and thus showing to what an extent mercantile transport economy by steam is affected by the proportions of length, breadth, and depth to which steam-ships may be built. For example: let us compare a ship of the type D, namely, length six times the beam, and load-draught two-thirds the beam,

TAB. B.—Showing the mutual relation of DISPLACEMENT, POWER, and SPEED of Steam-Ships, it being assumed that, for vessels of similar type of form, propelled by engines of proportionally equal efficiency, the law of variation is expressed by the formula $\frac{V^3 D^{\frac{2}{3}}}{\text{Ind. h.p.}} \propto X$, and that the present state of Steam-ship and Engine construction assigns a possible value to the coefficient X=250, V being the speed expressed in nautical miles per hour, D being the displacement at 35 cubic feet to the ton, and the unit of Indicated horse-power (h.p.) being equivalent to a weight of 33,000 lbs. raised one foot high in one minute of time.

SPEED { Nautical Miles per hour.	DISPLACEMENT IN TONS WEIGHT.																								
	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000	12500	15000	20000	25000
	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.	h.p.
6	34	55	71	86	100	114	124	137	148	159	169	179	200	221	235	252	286	315	345	372	400	466	524	638	739
7	54	86	113	137	159	179	200	218	235	253	269	286	317	345	373	397	452	500	549	592	635	738	835	1011	1173
8	81	128	169	204	238	269	297	325	352	378	400	424	473	511	559	593	676	747	818	885	952	1104	1242	1511	1751
9	116	183	241	291	335	383	421	463	500	537	573	604	669	731	790	845	963	1064	1166	1252	1339	1570	1773	2149	2393
10	159	252	330	399	462	524	580	635	687	738	783	831	921	1007	1090	1159	1321	1459	1597	1723	1849	2156	2436	2950	3420
11	211	335	440	531	614	697	769	845	914	981	1042	1104	1225	1338	1446	1546	1759	1942	2125	2290	2456	2870	3240	3926	4552
12	274	435	569	690	800	904	1000	1097	1183	1274	1352	1435	1590	1739	1880	2004	2277	2518	2760	2981	3202	3726	4206	5096	5910
13	349	552	725	877	1018	1149	1273	1395	1508	1620	1722	1825	2022	2208	2391	2550	2898	3203	3509	3790	4071	4737	5347	6479	7513
14	436	690	905	1095	1269	1435	1590	1742	1880	2023	2149	2280	2525	2760	2984	3184	3619	4000	4381	4729	5078	5917	6679	8094	9384
15	536	849	1114	1347	1563	1766	1956	2143	2315	2488	2616	2805	3108	3395	3671	3916	4454	4921	5389	5820	6251	7276	8218	9953	11542
16	650	1032	1352	1636	1898	2142	2374	2601	2808	3019	3212	3405	3771	4126	4457	4751	5406	5975	6545	7067	7590	8832	9974	12078	14008
17	780	1235	1620	1961	2273	2570	2846	3120	3367	3622	3850	4081	4519	4940	5344	5699	6479	7162	7845	8469	9094	10591	11961	14487	16802
18	926	1466	1923	2329	2701	3050	3381	3703	3999	4299	4568	4847	5368	5865	6344	6765	7693	8504	9315	10060	10805	12572	14197	17195	19945
19	1089	1725	2262	2739	3178	3588	3974	4355	4702	5057	5375	5699	6313	6900	7462	7959	9049	10003	10957	11833	12710	14790	16701	20227	23457
20	1270	2011	2638	3195	3705	4185	4637	5080	5485	5898	6269	6648	7362	8045	8704	9280	10553	11666	12779	13800	14821	17246	19475	23591	27359
21	1470	2332	3059	3698	4281	4858	5368	5880	6358	6828	7252	7700	8532	9329	10095	10736	12237	13515	14794	15960	17126	19969	22549	27310	31672
22	1690	2681	3517	4252	4922	5582	6172	6761	7311	7849	8339	8853	9808	10722	11609	12344	14069	15538	17008	18348	19689	22956	25923	31398	36415
23	1932	3064	4019	4858	5625	6379	7052	7726	8352	8969	9529	10115	11209	12224	13265	14104	16077	17755	19434	20967	22501	26230	29622	35876	41611
24	2194	3481	4567	5521	6391	7248	8011	8778	9491	10190	10826	11495	12734	13924	15070	16025	18268	20175	22083	23823	25564	29801	33651	40762	47277
25	2480	3936	5161	6239	7223	8194	9056	9921	10726	11517	12237	12993	14393	15746	17033	18112	20645	22801	24957	26925	28894	33682	38040	46068	53436

having weight-carrying capability or weight-tonnage of 2000 tons, with a ship of the same capability for carrying weight, but of the type I, namely, length eight times the beam, and load-draught one-third the beam. By Table A (columns 25, 26, 27 and 28), it appears that the ship of type D, of 2000 tons weight tonnage, will be 1680 tons builders' tonnage O.M., 1400 tons gross register tonnage N.M., and 3680 tons load-displacement; and by Table B, it appears that 950 ind. h.p. would propel this ship at the speed of 10 knots per hour; the consumption of coal at the rate of $3\frac{1}{2}$ lbs. per indicated horse-power per hour, would be 30 cwts. per hour; and supposing the engines, boilers, &c. to weigh one ton weight per five ind. h.p., the weight of these will be 184 tons; this ship may therefore be expected, on the data of the said Tables, to make a passage of 3500 nautical miles in 350 hours, consuming 525 tons of coal, and carrying 1291 tons weight of freight cargo. But what would be the case with the vessel of 2000 tons weight tonnage of type I? It appears that the builders' tonnage O.M. would be 5120 tons, the register tonnage N.M. 2720 tons, and the load-displacement 5480 tons; and by Table B, it appears that to propel this vessel at 10 knots per hour would require 1240 ind. h.p., these engines weighing 248 tons, and the consumption of coals 39 cwts. per hour; so that, on the data of the said Tables, this ship on the type I may be expected to make the passage of 3500 nautical miles in 350 hours, consuming 682 tons of coal, but carrying only 1070 tons of freight cargo. Hence it appears that with vessels of type D, we have expenses proportional to 1400 tons register N.M., and 950 ind. h.p., with income proportional to 1291 tons weight of freight; while with the ship of type I we have expense proportional to 2720 tons register N.M., and 1240 ind. h.p., with income proportional to only 1070 tons weight of freight; that is, the comparative prime cost expenses of transport in these two cases (assuming the cost incidental to one ind. h.p. to be equal to that of one ton of gross register tonnage) will be in the proportion of

$$\frac{1400 + 950}{1291} = 1{\cdot}82 \text{ to } \frac{2720 + 1240}{1070} = 3{\cdot}70,$$

or in the proportion of 1 to 2. Such is the effect of mere difference of proportion or type of build on mercantile steam transport economy. This example of a difference or extra cost of 100 per cent. on the prime cost rates of freight per ton weight of cargo conveyed on the same passage, and at the same rate of speed, is evidently occasioned by the load-draught of water being two-thirds of the beam in one case, that of the vessel D, and only one-third of the beam in the other case, that of the vessel I; and yet we see that the type or proportion of small load-draught in proportion to beam is a type or proportion of build, towards which the progressive increase in the size of shipping is gradually leading mercantile practice, as exemplified in the most extraordinary maritime enterprise of the present day, the 'Great Eastern.'

The mechanical advantage which attends progressive increase of size as measured by load displacement, is conspicuously shown by Table B, whereby we observe that a vessel of 250 tons displacement requires 274 ind. h.p. to attain the speed of 12 knots per hour, being very nearly in the ratio of one ton displacement to one h.p.; but, if the ship be 2000 tons, the ratio of displacement to power to attain the same speed (12 knots) will be 2 to 1; with a ship of 9000 tons it will be 3 to 1; and with a ship of 20,000 tons it will be 4 to 1. Hence a ship of the reputed size of the 'Great Eastern,' viz. about 25,000 tons load displacement, will require *proportionally* only about one-fourth of the power to attain a given speed that would be required by a ship of 500 tons displacement. Hence the great advantage of size, provided the

ship be of good type and can be always fully loaded; but seeing that load-draught is limited by local circumstances and other considerations which may not limit the length and breadth, it becomes a matter of calculation to determine at what point the admitted advantages of size become neutralized with reference to any particular service by the limitation of load-draught in proportion to beam. Let us have all the advantages we can get, without running into extremes, by which those advantages become sacrificed.

Are not public interests involved in this matter, and is it not a matter of grave importance, meriting the attention of the British Association? I beg to conclude with the suggestion, that it is only by statistics that the deficiencies of our present maritime system can be properly searched into and brought to light; and it is only by the force of statistical exposition that the required remedies can be devised. It is therefore respectfully submitted, that the constructive type of shipping as respects the proportions of length, breadth, and depth, constitutes a subject of inquiry which merits the notice of the Statistical Section of the British Association.

Further Report on the Vitality of the Spongiadæ.
By J. S. Bowerbank, *LL.D., F.R.S. &c.*

[With a Plate.]

In the Report on the Vitality of the Spongiadæ which I had the honour of reading to the Association at Cheltenham last year, I detailed a series of observations on the inhalation through the pores and the exhalation of water through the oscula of a marine British sponge, *Hymeniacidon caruncula*, Bowerbank, MS., and I was enabled to determine with certainty the capability which that sponge possesses of opening and closing the oscula at its pleasure; but I could not in that series of observations satisfactorily determine the nature and powers of the imbibing pores, as these organs can only be seen distinctly in operation in very young and transparent specimens. I therefore determined to confine my researches on this subject more especially to *Spongilla fluviatilis*, specimens of which may readily be obtained of small size and under very favourable circumstances for the observation of the porous system. On the 13th October, 1856, my friend Mr. H. Gilbertson, of Hertford, brought me several young specimens of this species, one of which had attached itself to a watch-glass, in which it had been kept for observation. The point of attachment was a thin membrane projected from the edge of the sponge (*a*, fig. 1, Plate I.), having in it a few single spicula irregularly disposed, and with very little appearance of sarcode upon it; and above the thin attached membrane there was a second one, which was a prolongation of the upper surface of the sponge. The body of the sponge was thin, concave at the upper and convex at the lower free surface. It was nearly circular in its outline, and rather exceeded half an inch in diameter. At one portion of the margin it had been recently extending its dimensions, and the space intervening between the old surface and the new one had the appearance of being one large cavity, the new dermal membrane being forced outward and supported from the points of the radial lines of the spicula of the newly produced portion of the skeleton, the outer surface of the membrane curving inward, from point to point, in a manner that plainly indicated the forcible

pressure outward of the newly-formed radial lines of the skeleton. At a short distance within the margin, and in the neighbourhood of the newly-produced portion of the sponge (*b*, fig. 1), there was a single osculum situated on a large oval bladder-shaped projection of the dermal membrane, which varied considerably in its form according as the sponge was inert or in action. When in the former state it was frequently in a semi-collapsed condition, the apex being considerably attenuated, so that the whole assumed an ovate form, the smaller end being the distal one, and in that condition not the slightest orifice was visible, the osculum being entirely closed, and what was very remarkable, its place was not even indicated by an apparent thickening or corrugation of the membrane. On the contrary, when in action the bladder-shaped projection was dilated at the apex so as to cause it to assume a regular oval form, and the osculum was apparent in the form of a large circular orifice, about one-fourth the size of the diameter of the bladder-like portion on which it was situated (fig. 2). From this orifice a powerful stream of water was continuously ejected, and large and small patches of fæcal matter were frequently thrown out with considerable force.

When a small portion of pure indigo was rubbed up in water, and a drop or two of the water laden with this substance was mixed with that in the watch-glass, and it was placed beneath the microscope with a power of 130 linear, and a strong light passed through it from a concave mirror, at first no action was apparent, the osculum was in a completely closed condition, and although I searched the surface of the newly-formed portion of the sponge with the greatest care and attention, I could not detect a single open pore. In rather more than half an hour I found one open, and in a short period others gradually and successively made their appearance, until at last, in one of the spaces between two of the radial lines of the skeleton, I readily counted as many as 10 in a fully expanded and active condition, and in other similar spaces they were apparent in considerable numbers. The action presented to the eye was exceedingly interesting. The molecules of indigo approached the surface of the sponge at first slowly, their motion being gradually accelerated as they became nearer, until at last they sprung as it were with avidity into the pores; within the sponge some passed to the right hand, while others took their course to the left, and they often passed other molecules which had entered by other pores, and which were passing in a contrary direction. Many of these molecules might be readily followed, as they meandered through the interior of the sponge, and might be seen flowing in every direction. During the maintenance of this action in full force, when I directed my observations to the osculum, it was seen pouring forth a continuous stream of water and along with it masses of flocculent matter, and many of the larger molecules of the indigo that had entered by the pores; but it is remarkable that although the finer molecules of indigo were being imbibed by the pores in very considerable numbers, very few indeed of them were ejected from the osculum; and if the imbibition of the molecules continue for half an hour or an hour, and then cease, the sponge is seen to be very strongly tinted with the blue colour of the indigo, and it remains so for at least 12 or 18 hours, after which period it resumes its original pellucid appearance, the whole of the imbibed molecules having undergone digestion in the sarcode lining, the interior of the sponge and the effete matter having been ejected through the osculum. After having watched the active operations of the sponge for nearly an hour, I set to work to sketch the field of view in the microscope, in order to mark the position of the pores; but by the time the outline of the sketch was completed, about half an hour, the action had ceased, the pores were entirely closed, and my further

proceedings, as regarded their delineation, were deferred to a more favourable opportunity.

On the 14th the sponge was in a quiescent state, and strongly tinted by the indigo imbibed on the previous evening.

15th October.—I examined the Spongilla at $\frac{1}{2}$ past 10 A.M.; there was no action to be detected, and a considerable tint of colour was still visible: at 9 P.M. I placed it under the microscope; it was then free from colour and in full action. The tube bearing the osculum was very different in form from what it was on the evening of October the 13th, when at 11 P.M. it was in form and proportions like an olive (fig. 2); at 9 P.M., on the 15th, it was in form and proportions like the last two joints of a man's finger, slightly bent at the last joint (fig. 3). At 10·30 of the same evening, when the action had grown very languid, the basal portion was very much expanded, and the whole assumed the form of a cone, the apical portion of which had fallen over on one side, and the excurrent stream was directed towards the body of the sponge at an angle of about 45 degrees to its plane (fig. 4); it is evident, therefore, that this organ assumes a great variety of forms.

At 9 P.M., when I commenced my observations, the portion under examination was crowded with pores in a fully expanded condition, and I immediately mixed a drop of water charged with indigo, with that in the watch-glass, and the imbibition of the molecules continued steadily until 10·30 P.M., when it suddenly became very languid; at this period I directed my attention for a few moments to the osculum, and on again returning to the observation of the pores, I found nearly the whole of them completely closed. I examined some of the largest of the pores with the utmost care for more than an hour with a power of 260 linear, but I could not detect cilia either at the margins or within the entrance. When the incurrent action became rather languid, I observed that the molecules within the sponge were performing a sort of cyclose circulation, frequently rising up and passing across the open pores, but never coming out through them; but while this action was going forward, now and then a molecule of indigo would pass languidly into the pore. It would seem, therefore, to indicate that the organs of incurrent action were situated, as I have long suspected, within the large intermarginal cavities, as in *Grantia ciliata*, and not immediately around or within the pores.

During the continuance of vigorous incurrent action, the water charged with indigo is in continual motion, flowing from all quarters towards the open pores; many of the molecules come in contact with the portions of the skeleton projected through the dermal membrane, and wherever they touch, they adhere tenaciously to the adhesive matter coating those parts, in the same manner as they do to the sarcodous membranes within the sponge; but the same results do not seem to follow with those without, that occur with those within. On the evening of the 15th, when I terminated my observations, I left the sponge with an abundance of molecules attached to the internal tissues, and a considerable quantity of similar molecules fixed to the external fasciculi. On examining the same sponge at 11 A.M. on the 16th, I found the external tissues with the molecules still adhering in considerable quantities, but the internal ones were perfectly free from the coloured particles. The excurrent tube still retained much the same form that it had on the termination of my observations on the previous evening, but it was in a more collapsed condition, and instead of the osculum being a well-defined circular orifice, it had assumed a much smaller and more irregular shape, and was puffed out from the end of the excurrent tube in the form of a loose hemispherical appendage to its apex, from which a molecule now and then came

languidly forth (fig. 5). On examining the pores I could not find a single one open.

I again examined the same sponge at 8 P.M. of the 16th October. The excurrent tube bearing the osculum was nearly erect (fig. 6), and the stream was slowly pouring forth. I examined the usual part for the pores, and found very few that were in a slight degree opened. I then directed my attention to the thin stratum by which the sponge was attached to the watch-glass. Hitherto I had not detected any pores in that part of the sponge, but this evening I saw several which were open, and into which the floating molecules were steadily entering. I selected one spot for observation, where there were several pores indistinctly visible: in about 5 minutes they became very much more distinct, fully expanded, and the margins assumed a thickened and well-defined outline; others made their appearance, and at last fourteen were in a fully expanded and active state (fig. 8). I immediately put a drop of water charged with indigo over the pores; the molecules were absorbed with great rapidity, and the rush of the indigo to the pores became so great that its accumulation rendered the sight of them indistinct, and to clear the sponge from the indigo I sent a puff of air from my mouth on to the surface of the water in the watch-glass, but doing this rather too roughly, I turned the sponge over on its flexible base, as it were on a hinge; I therefore removed it and placed it in a basin of fresh water to float it back again into its proper position, and immediately replaced it under the microscope, the whole operation not occupying more than a minute; but on getting the precise spot into focus, I found not a single pore open: the sudden violence done to the sponge had caused a complete cessation of action and a perfect closing of the inhalent pores. This result is curious, in contrast with the fact, that the sponge endures a large Vibrio, which is continually crawling with considerable activity over its surface, and frequently biting large mouthfuls out of the soft tissues, without appearing to create the slightest alarm, although passing immediately across the pores while in full action.

18th October.—At 11 P.M. I resumed my observations at the precise spot which I had examined on the evening of the 16th, and of which I then took a sketch. Not one of the pores that I had carefully diagrammed opened during an hour and a half that I constantly observed them, but several others close by the spot were fully expanded, and were steadily imbibing the molecules of indigo with which I supplied them. I selected three of these for observation, but with a power of 260 linear I could not detect cilia. The mode of the entry of the molecules was regular and very remarkable: they approached the pore by a steadily accelerated motion, and when they reached the margin rushed suddenly into the orifice; but although entering thus forcibly, their course was not straight downwards, but each one seemed to slip as it were round the margin and pass rapidly off at an angle of 45 degrees immediately beneath the dermal membrane, and their course might be traced for a considerable distance in a straight line, and with a gradual decrease of speed from the moment of their entrance. These circumstances would seem to indicate the position of the motive power to be immediately within the margin of the pore, but I could not in any case detect them; I sometimes saw a hazy rim immediately within the pore, but I believe this was due to parallax arising from a slight change in the position of the dermal membrane. The peculiar mode of the entry of the molecules, combined with the cyclose circulation that I have previously noted as occurring when the inhalent action became languid, induces me to believe that the seat of the cilia is confined to the large intermarginal cavities of the sponge, and that they are not appendages of either the pores or the oscula. At the end of an hour and

a half of close observation with the hope of detecting the act of the closing of the pores, I was rewarded for my patience by seeing that the clear tense rounded margin of one of them, which was black by the aberration of the rays of light passing through it, began to lose its distinctness, and at the same time it assumed an irregularly oval instead of a circular form. The margin melted away, as it were spreading gradually inward towards the centre, and this action continued until the orifice became entirely closed, and not the slightest mark remained to indicate the place a minute previously occupied by a fully expanded pore. When thus closed, the membrane presented precisely the same irregularly granulated appearance that characterized the surrounding tissue. Two other pores in the immediate neighbourhood underwent precisely the same process in the course of less than a minute.

October 19th.—At 9 P.M. I found the sponge in very languid action, and completely clear internally of molecules and indigo. The excurrent tube bearing the osculum had assumed a new aspect. In addition to the usual conical projection of membrane, the apex was dilated into the form of a supplementary, obtusely oval bladder, terminated by the usual osculum in a fully dilated condition (fig. 7). Through this orifice, in consequence of its favourable position, I could focus clearly, down to the body of the sponge, and had there been cilia lining the interior surface of the tube, I could not possibly, I think, have missed seeing them; but I failed in detecting the slightest indication of their presence : very few pores were open, and none of those which I had diagrammed carefully on the 16th, nor any of those which I had observed on the 18th.

I continued to observe this and several other small specimens of Spongilla for several weeks, but as the results were with very little variation the same as those I have previously described, it is unnecessary to detail them.

The observations on Spongilla, as regards the forcible and the languid exhalation, are in perfect accordance with my description of those actions in the marine sponge *Hymeniacidon caruncula*, recorded in my report "On the Vital Powers of the Spongiadæ," published in the Reports of the British Association for 1856, p. 438. The vigorous imbibition and ejection of the surrounding water is as strikingly indicative in the freshwater sponge as it was in the marine one, of the period of feeding; while the languid action in either case distinctly marks the aërating process only, during which the digestion of the nutritive particles previously imbibed is gradually effected, and the effete matter partially ejected. In the performance of these instinctive acts, Spongilla possesses the same degree of control over these actions that I have described in my former report as existing in the marine sponge; sometimes the rapid ejection of the excurrent stream in the Spongilla was suddenly brought to a conclusion, while at others there was a very gradual decline in the rapidity of the action until it assumed the degree of force that marks the excurrent streams of the breathing action only.

The structure of the pores, and the perfectly plastic nature of the dermal membrane, as exhibited in these observations, are very remarkable. The sensitiveness of the sponge to injury, the rapidity of the act of closing those organs, and the power they appear to possess of opening new ones to any extent and in any direction they please, attest an astonishing amount of vital energy in a membrane in which I have been unable to trace any indication of the existence of fibrous tissue.

On Flax. *By* John P. Hodges, *M.D., F.C.S., Professor of Agriculture, Queen's College, Belfast, and Chemist to the Chemico-Agricultural Society of Ulster.*

Composition of the Unsteeped Flax Stem and of the Dressed Fibre.

For the purpose of studying the nature of the proximate compounds which are contained in the cells of the flax-plant, and which are in part removed in the steeping process, several analyses, both of unsteeped and of dressed flax, *i.e.* of the fibre in the condition in which it is brought into the market, deprived of the portions unsuitable for spinning, have been made by the Reporter. By operating upon large quantities of material, he was enabled to separate considerable quantities of some of the most important constituents of the plant, and had hoped to be ready to communicate the results of the investigations in which, at various periods during the past three or four years, he has been engaged; but, from the interruption of pressing professional duties, he has been obliged to remain content with merely a partial survey of the subject. As, however, the chief labour of the investigation has been removed, he expects that, in the course of next year, he may conclude the inquiry. In the mean time, a summary of some of the results obtained will be found interesting, and in some degree useful, as a contribution to the chemical history of a material of so great importance to the staple industry of Ireland. For the proximate analyses of the plant, various methods of investigation were tried; but that which was preferred, as affording the most reliable results, was conducted as follows:—The flax, cut into small pieces, was in the first place repeatedly treated with cold water, so long as anything was dissolved. The solution was strained through linen, and afterwards filtered and heated to ebullition. The coagulum which was produced on boiling the liquid was separated by the filter, and a few drops of acetic acid added, which produced a precipitate of caseine, which, after twelve hours' subsidence, was collected, washed, dried, and weighed. In the liquid from which the caseine was separated, when evaporated to an almost syrupy consistence, alcohol, when added, produced a bulky gelatinous precipitate of a greyish colour, which was collected on a filter, washed with alcohol, and dried. The alcoholic liquids, on concentration, afforded rich orange-coloured solutions, and afforded, on evaporation, reddish-brown extracts, which, in the case of the dressed flax, were found to contain a considerable amount of grape-sugar. The several precipitates and residues, after being weighed, were carefully incinerated, and the weight of ash obtained in each case deducted. The amount of nitrogen contained in the samples was determined by the method of Varrentrapp and Will, and in each case two estimations were made—first, of the total amount of nitrogen contained in the specimen dried at 212°; and secondly, of the amount of nitrogen which was retained, in the form of insoluble azotized compounds, in the specimen from which all soluble matters had been removed by treatment with water as described. The amount of fatty matter and oil present was obtained by treating the specimen dried at 212° in a simple, but exceedingly effective, extraction apparatus, which for upwards of ten years has been in use in the laboratory of the Reporter, and has been found of great service in facilitating the treatment of substances with alcohol and æther. It is formed by attaching a thin glass flask, capable of containing about 6 oz. of liquid, by means of a small glass tube and sound corks, to a glass vessel of about 12 oz. capacity provided with two openings, one being at the top and the other at the side, as close as possible to the bottom of the vessel. To the opening at the top of the vessel, a glass tube bent at right angles is affixed by means of a cork,

and its longer limb made to pass to the bottom of a loosely-closed vial which is placed in a beaker containing some cold water. The apparatus thus constructed consists of three vessels; and the material to be extracted, reduced, if possible, to coarse powder, or cut into small pieces and bruised, is placed in the intermediate vessel, the lower tubulure of which should be loosely filled with a piece of cotton which has been previously boiled with æther and alcohol. A little flask, in which about an ounce of æther has been placed, is then attached, and the bent tube inserted, with the long limb passing into the vial, in which also there is some æther. The apparatus being thus arranged, a spirit-lamp is held under the little flask, and the heat continued until nearly all the æther is volatilized. The flask is then, without being detached, cooled by immersion in a basin of cold water, when the æther in the intermediate vessel, and also that in the condenser, is forced into it by atmospheric pressure. The flask is then dried by blotting-paper, the heat of the lamp again applied, and the process continued until the æther which passes through the little bent tube connected with the flask is entirely free from colour. By this method of extraction, nearly all the æther employed can be recovered by applying heat to the flask, so as to cause the liquid to accumulate in the condenser, and a concentrated solution of the matter dissolved is collected in the flask. By placing the flask (the weight of which has been ascertained) in the water-bath, so as to remove all traces of the solvent, the amount of the extract can readily be determined.

The total amount of matters extracted by æther, in five experiments, with samples of flax-straw, the produce of crops in this country, in different years, and all of first-rate quality, gave an average of 2·068 per cent. on the flax dried at 212°. The residue of the flax, after extraction with water, and the subtraction of the amount of wax, &c. extracted by æther, and of the insoluble nitrogenized compounds, as calculated from the amount of nitrogen in the washed fibre, and assumed to possess the composition of albumen, and of the insoluble inorganic matters which it was found to contain, was regarded as fibre.

The following is a statement of the results obtained in the examination of samples of dressed flax fibre, of average quality, and also of a sample of unsteeped flax-straw which had been taken from the field when fully matured, and had remained for some weeks in the stack. The samples of fibre dried at 212° contained, respectively—No. 1, 9·10, and No. 2, 8·61 per cent. of water; and the unsteeped straw 12 per cent.:—

	No. 1.	No. 2.	Unsteeped Straw.
Wax volatile oil, lino-tannic acid, and resinous matter	2·200	2·620	1·360
Sugar and colouring matter, soluble in alcohol	1·541	0·624	5·630
Inorganic matters, soluble in alcohol	0·281	0·116	2·830
Pectine	0·698	0·280	0·360
Salts, insoluble in alcohol	0·076	0·044	0·080
Nitrogenized compounds, soluble in water, caseine, &c.	3·560	1·380	0·834
Nitrogenized compounds, insoluble in water	2·940	4·310	4·269
Inorganic matters, united with the fibre	0·730	1·490	2·500
Fibre	87·974	89·136	82·137
	100·000	100·000	100·000

The total amount of inorganic matters present in the samples was obtained by the careful incineration of the flax in platinum dishes. The specimens of fibre dried at 212° gave, respectively, in No. 1, 1·40 per cent., and in No. 2, 1·54 per cent. of ash. The ash had a brick-red colour. The unsteeped flax left, on incineration, 5·23 per cent. of an almost white ash. The ash from the fibre had the following composition:—

	No. 1.		No. 2.
Potash	7·94	...	1·85
Soda	2·19	...	7·62
Chloride of sodium	2·75	...	1·77
Lime	29·24	...	27·08
Magnesia	4·64	...	0·70
Peroxide of iron	3·72	...	7·40
Phosphoric acid	5·23	...	10·40
Sulphuric acid	6·00	...	3·12
Carbonic acid	28·17	...	19·10
Silica	10·45	...	21·31
	100·33		100·36

By distilling the straw of the flax plant with water, there is obtained in the receiver a slightly acid distillate, from which, when saturated with common salt, by treatment with æther, there is procured a small amount of an exceedingly fragrant oil, of a yellow colour, which possesses an intense honey-like odour. This oil, when heated, evolves a penetrating smell, with a somewhat turpentine odour. It soon solidifies on exposure to the air, forming irregular granules, and acquires an acid reaction. Its dilute solution evolved the characteristic agreeable odour which is perceived in rooms in which large quantities of dressed flax are stored. It may also be separated by adding water to the solution, obtained by treating the straw with alcohol in the extraction apparatus, and subjecting the mixture to distillation. By the action of æther upon both the unsteeped and dressed flax, rich green-coloured solutions are obtained. These solutions possess a strongly acid reaction, and, on partial cooling, bulky, flocculent white deposits separate, leaving the supernatant liquid of an emerald-green colour. The deposited matter soon collects in transparent granules, and, when repeatedly washed with cold æther, which separates from it a yellow colouring matter, it dries over the water-bath to a slightly yellow brittle pulverulent extract, which in the cold is scarcely at all acted upon by absolute alcohol, but dissolves by the assistance of heat in spirits of turpentine and in ammonia, and is saponified by heating with solution of caustic potash. Fixed on a loop formed on a piece of platinum wire, and exposed, with the usual precautions, to water heated over a lamp, it was observed, in several trials, to soften at the temperature of 182° Fahr., and to melt at 184°·5 Fahr.; strongly heated in a platinum capsule, it runs along the dish, then melts and evolves an odour of wax, and when placed in its melted condition on paper, produces a greasy stain. The amount of wax separated from the unsteeped flax amounted to 0·27 per cent.

When the solution obtained by treating the flax-straw with æther is evaporated to dryness, a residue is left which consists of a deep olive, almost black extract, mixed with a substance of a rich orange colour. This extract, on being dissolved by the assistance of heat in æther, and distilled water added to it, produces a brown turbid solution, on the surface of which a dark brown sticky matter collects, which, when removed by filtration, leaves the liquid of a bright golden-yellow colour, and affords, on evaporation, an orange

strongly acid extract, which was found to consist chiefly of a peculiar tannic acid, which strikes a deep green colour with the persalts of iron. This acid, which may provisionally be termed lino-tannic acid, was also obtained in white needle-shaped crystals, by adding neutral acetate of lead to the æthereal solution of the plant, and decomposing the lead compound diffused in alcohol by sulphuretted hydrogen. The filtrate from the sulphuret of lead, which had an orange colour, when evaporated to dryness, afforded on treatment with æther, a solution from which, when the æther has spontaneously evaporated, crystals of the acid separated. The acid, though existing in minute quantity in the plant, has been detected both in the unsteeped and dressed flax, and possesses considerable interest in connexion with the technical preparation of the fibre, as its presence explains the discoloration which is frequently observed when the flax-straw has been steeped in water containing salts of iron. In addition to the lino-tannic acid, the straw of the flax plant was found to contain a considerable amount of malic acid, and also an acid yellow colouring substance of a resinous nature, which can be extracted by alcohol, and yields, with basic acetate of lead, a rich chrome-yellow-coloured precipitate, which, when suspended in alcohol and decomposed by sulphuretted hydrogen, and the sulphuret of lead removed, yields a straw-coloured liquid, from which, on evaporation, the resin is obtained in the form of a tenacious orange-brown extract, which is insoluble in æther, but dissolves readily in alcohol, and is precipitated from its solution in the form of a buff-coloured mass, which is dissolved by alkalies, with the production of a rich orange-coloured solution.

From the green plant, and also from the dressed fibre, water extracts a gelatinous substance which is thrown down as a bulky precipitate on the addition of alcohol. This precipitate was found to consist of pectine with malate and sulphate of lime. In the unripe plant, and also in the stems, as pulled from the field in the usual state of maturity, when the seeds contained in the capsules have commenced to assume a brown colour, starch was discovered, and could readily be extracted by placing the stems in a powerful lever press, and moistening them with a small quantity of water. By allowing the expressed liquids to remain at rest, the starch subsides, and can be recognized by the microscope as consisting of extremely minute corpuscles, which assume a purple colour on the addition of a watery solution of iodine. When, however, the flax-straw is examined after it has remained exposed to the air for several days in the stook, the liquid obtained by subjecting it to pressure and washing with water was found to afford no indication of the presence of starch. In the dressed flax, no starch could be detected, but the presence of a considerable amount of grape-sugar was demonstrated. The discovery of grape-sugar in the fibre is in many respects exceedingly interesting, as it serves to afford an explanation of the statement frequently made by experienced steepers, that, by storing up the steeped flax as imperfectly dried, by exposure to the air for some weeks before proceeding to remove the adherent woody matters by mechanical means (by scutching), the separation of the fibre is found to be greatly facilitated, and its qualities improved.

Examination of the Steeping Process.

As stated in former communications to the Section, experiments, which were conducted by immersing flax in water, both at ordinary temperatures, and also in vats filled with water, heated and steadily maintained at from 80° to 90° Fahr., have shown that in both cases the series of decompositions which ensued might be regarded as identical, and that the fermentation

which takes place resembles the so-called butyric acid fermentation. Thus, when the gases which are evolved from the surface of the steeping vats are collected, which is most conveniently effected by filling the receivers with the flax water and supporting them over the surface of the liquid, the mixture of gases obtained, when transferred to the mercurial trough, and examined by the introduction of pellets of potash, explosion of the residue with oxygen, &c., according to Bunsen's excellent methods, was found, in numerous trials, to afford merely carbonic acid, hydrogen, and nitrogen. In no case could traces of carbonic oxide, carburetted hydrogen, nor of sulphuretted hydrogen be detected. The absence of sulphuretted hydrogen was carefully ascertained by the employment of various methods; not the least indication of its presence could be detected, though papers moistened with acetate of lead were exposed to the gases evolved during the entire progress of the fermentation. This fact is important, as it has been asserted that the disagreeable odour of the flax-pool depended upon the copious evolution of sulphuretted hydrogen; and its presence in the gases evolved has been reported by a French chemist, though upon insufficient evidence, afforded by the examination of flax-water, conveyed in bottles from remote parts of the country to Paris. The production of a large amount of sulphuretted hydrogen has been urged as a serious objection to the adoption of Schenck's hot-water process.

The corrected composition of 100 volumes of the mixed gases evolved from the fermenting vats was found to be as follows:—

Carbonic acid	22·29
Hydrogen	44·30
Nitrogen	33·41
	100·00

At the Belfast meeting of the Association, it was stated by the Reporter that, during the fermentation, a very considerable amount of butyric acid was produced. Since that period, the experiments have been repeated on a considerable scale, and it has been found that, though, when the fermentation has fairly commenced, after the straw has been about twenty-four hours immersed, the distillate from the fermenting liquid contains formic acid and butyric acid; yet, as the process continues, and especially towards its conclusion, the formic acid almost entirely disappears, and the butyric acid decreases in amount, and is replaced by valerianic acid. In some cases, indeed, the distillate, towards the conclusion of the period of steeping, afforded nearly pure valerianic acid.

Report of the Committee on the Magnetic Survey of Great Britain. By Major-General Sabine.

The author gave a brief review of the important researches connected with the magnetism of the globe by MM. Kreil and Lamont, on the Continent of Europe, Dr. Bache and others in America, and by our own observers in various parts of the earth. He adverted to the Magnetic Survey of the British Islands, executed at the request of the British Association in 1837 and 1838, published in the 'Reports' for 1838, as the first national work of this description which had been executed in any country, and to the similar works since completed in Austria and Bavaria, at the expense of the Governments of those countries, in proof of the value of the example. It is on such

surveys that we must in great measure depend for the materials on which correct delineations of the three magnetic elements on the surface of the earth can be satisfactorily based; and it is to the *repetition* of such surveys, from time to time, that we must look for the data on which a true theory of the secular variation of terrestrial magnetism may be founded. Twenty years having elapsed since the execution of the former Magnetic Survey of the British Islands, the General Committee had deemed that the proper time had arrived for its repetition, and named a Committee for the purpose, consisting of the same five members of their body by whom the former survey was made, with the addition of Mr. Welsh, the Director of their Establishment at Kew. The present Report stated the progress which the Committee had already made, chiefly in England and in Scotland, and their expectation that at the next meeting of the Association they should be able to report that the work was drawing near to its completion.

Report on Observations of Luminous Meteors, 1856–57. *By the* Rev. BADEN POWELL, *M.A., F.R.S., F.R.A.S., F.G.S., Savilian Professor of Geometry in the University of Oxford.*

IN submitting to the British Association my *tenth* Report of Observations on Luminous Meteors, I could have hoped that it might have contained some attempt at least towards the classification and generalization of the vast mass of results which have now been communicated. But while the actual contribution of fresh observations for the year which has elapsed since my last communication is not very extensive, I am also constrained to admit that I have as yet attempted very little towards the greater object in view.

In the present communication, nevertheless, besides the mere detail of observations, I am able to include notices of one or two important speculations on the subject which have been pursued by some eminent men who have turned their attention to this inquiry, and have followed out some generalizations on certain points connected with it, which seem eminently valuable towards the gradual establishment of a solid theory of meteoric phænomena.

I. Some generalizations respecting the causes of meteor-phænomena, especially the averages of their *horary variation* in numbers through the night, have been advanced by Mr. G. C. Bompas, founded on the observations of MM. Coulvier-Gravier and Boguslawski.

The general result of those observations is, that the number of meteors varies through the successive hours from 6 P.M. to 6 A.M., by a *regular increase* up to the last-named hour.

The number which appear in the East is more than double the number originating in the West; those from North and South nearly equal. In other words, nearly two-thirds of the whole number originate in the Eastern hemisphere of the sky.

From the observations of Boguslawski and others, it appears that the *average velocity of meteors* is about *double* that of the *earth* in its orbit.

Mr. Bompas, combining these facts, deduces the following theory, derived solely from the conditions of the earth's motion. The greatest number of *meteors* is encountered when *the observer's meridian is in the direction of the earth's motion*, which is at 6 A.M.; and then decreases to 6 P.M., when he looks the opposite way. If the earth were at *rest*, meteors (supposed equally

distributed) would converge on it equally from all quarters. But the earth, in fact, being in motion with *a velocity half that of the average velocity of the meteors*, it encounters nearly two-thirds of the number *on the side towards which* it is moving.

II. A considerable series of results has been investigated by M. A. Poey, respecting the *colours* of luminous meteors, derived from extensive sets of observations collected by M. Ed. Biot from those made in China from the 7th century B.C. to the 17th A.D.;—those collected in the Reports of the British Association;—and those made at Paris by M. Coulvier-Gravier.

Among these generalizations we may remark the following:—

In the Chinese observations meteors of simple *primitive* colours are very *rare*, the great majority being of compound tints; in the European observations the *reverse* is the case.

The Chinese observations show a remarkable constancy of tints during a long period of years, when an equally constant but different scale of colour prevails; and this for several successive periods.

Cases of *complementary* colours in the body of the meteor and the train, or fragments, are often noticed.

Changes of colour *during the course* of the meteor are observed, being most usually from *white* near the zenith to *blue* near the horizon, but sometimes from *white* to *red*. This, the author observes, agrees with the law of M. Doppler, that a luminous body moving *towards* the observer will change its colour from white, in succession to the *violet* end of the spectrum;—moving *from* the observer, to the *red*. This law, he states, is especially confirmed by the Paris observations. He remarks on the necessity for attending to *personal* differences in observers' estimate of colour; a remark fully confirmed by the great contradictions existing in the descriptions of the *colour* of many of the brightest meteors, at the same time and place, by different observers.

He gives the results of the various observations cited, in tables exhibiting the number of meteors of each tint for each month; and adds others of meteors arranged under several heads, of physical peculiarities.

The details are given in the Appendix No. 4.

III. One point of the highest interest and importance towards forming any sound theory of meteors, is the estimate of *their actual size* from their *apparent diameters* and calculated *distance*. In all the results usually given this calculation is made on acknowledged geometrical principles, *assuming* that the *apparent* disk is the *real* one, diminished *only* by the effect of *distance*.

Prof. J. Lawrence Smith of the U. S. has adduced some very remarkable optical experiments to show the *entire fallacy* of any conclusion from the *apparent* diameter of a highly luminous or incandescent body seen at a distance.

These experiments exhibit a singular apparent enlargement of the visible disks of intensely luminous bodies of known size, when observed successively at distances of 100 yards, of a $\frac{1}{4}$ mile, and $\frac{1}{2}$ mile; at which distances respectively, for example, the body of electric light of carbon points (actually 0·3 inch diameter) appeared $\frac{1}{2}$, 3 times, and $3\frac{1}{2}$ times the diameter of the moon; and other incandescent bodies in a similar proportion dependent on the degree of ignition.

These results seem dependent on some optical or ocular cause, of greater energy than we can ascribe readily to simple irradiation; but in a rough way they admit of some degree of verification by looking at a row of street lamps seen nearly in a line from the eye, the apparent diameters of which do not

decrease at all for a considerable distance; and even then by no means in proportion to the law of perspective.

This subject appears to be one eminently deserving of more full and precise investigation, whether in a meteorological or an optical point of view.

IV. Prof. Lawrence Smith's paper is, however, mainly devoted to other points of not less importance respecting the nature and theory of meteors, and especially of those which fall either wholly or in portions, producing meteoric stones.

He gives a minute account of five specimens found in America, accompanied by chemical analyses, from which it appears that they all contain the mineral called Schreibersite, not known as a natural compound on the earth. He enters largely on theoretical views, and in the course of these speculations examines various hypotheses which have been put forth, and eventually endeavours to revive the theory of the origin of these bodies from the *lunar volcanoes* supposed at some remote period to have been in a state of activity.

Without discussing such a question, which will perhaps be generally viewed with suspicion at the present day, and passing to the general subject of shooting stars, which the author is inclined to distinguish entirely from those masses which have fallen to the earth, we may notice the apparently favourable mention he makes of the general admission of the cosmical nature of the former, and of that view of their nature which regards them as *nebulous masses* revolving in our system.

It has been further supposed that such masses, being in a high state of electric tension, on approaching the earth, a discharge might take place by which their metallic elements might be reduced: dependent on the size of the nebulous mass, the force of the discharge, the consequent intensity of the fusion, and other conditions, larger or smaller metallic or earthy masses might be precipitated, and might fall entire or shattered into fragments. The author, however, considers these latter effects as incompatible with the conditions of observed meteorites.

But probably, on the whole, all such speculations are as yet premature. We must obtain a larger amount of data and better classification of observations before we can hope to follow out such inferences successfully.

For the details of Prof. L. Smith's paper see Appendix No. 5.

V. In some of the earlier of this series of Reports, reference was made to the theory proposed by Sir J. Lubbock, of meteors shining by *reflected* light and being simply darkened by entering the earth's shadow, and to some observations of meteors which coincided with it. It is much to be regretted that other observations of a kind capable of such application have not been more frequent. One remarkable instance observed by Capt. Jacob, at Bombay, was considered some years ago by Prof. C. P. Smyth, and a communication on the subject made by him to the Royal Society of Edinburgh (1849), of which a short notice in the Proceedings of that body is the only remaining record—the details having unfortunately not been preserved. The results, however, are stated to accord exactly with the theory.

The essential parts of the notice are given in Appendix No. 6.

VI. Of the August meteors for the present year, the only notice which has reached me has been an account published by Dr. T. Forster, of Brussels, in the *Times*. He observed great numbers, some of them presenting unusual appearances, especially in regard to colour.

His letter is given in Appendix No. 7.

Meteors communicated by

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1856. Jan. 7	h m 4 50 p.m.	A fire-ball	Bright and red	Left a column of thin vapour which wavered and gradually vanished.	Visible for 20 mins.
	4 50 p.m.	A luminous vertical band expanded at the middle, with a bright centre tapering to the ends, intensely bright and white.	....	The middle expanded and ends curved opposite ways, became faint and vanished.	Disappeared after about 10 minutes.
Oct. 18	Mean time at the place. 9 4 p.m.	Nearly = ♃	....	Small train of sparks left behind.	....
Nov. 15	5 58 p.m.	Brighter than any stars visible through the rain.	....	....	Slow................
22	7 16 p.m.	Just visible through clouds.	....	....	....
1857. Jan. 2	Between 2 a.m. & 5 30	A number of small meteors.	....	....	....
1856. Aug. 10	From 9 p.m. to 10 p.m.	Five bright meteors at different intervals of time. Several smaller.	Two very bright.	The brightest left a train, which remained 1 or 2 seconds. The head moved on separately, became stationary, and vanished by gradual diminution.	Rapid ....
Oct. 19	6 24 25 (G.M.T.)	A very brilliant meteor. = 2nd mag. Increased to = ♃ and exploded with sparks.	Bluish. Intense at explosion.	Left a bearded train behind.	Slow; about 3 sec.
Nov. 30	7 17 p.m. (G.M.T.)	= α Lyræ..............	Light orange..	No train	Rapid ....
Oct. 30	8 1 p.m.	Bright; = ♃; disappeared suddenly near ε Ursa Major.	Colour of ♃...	Very little train	Moderate velocity; 2 or 3 secs.
28, 29, 30, 31		Brilliant meteors "all over the sky."	....	....	....
29	6 30 p.m.	A fine meteor	....	Exploded fragments "pursued the path the meteor itself had taken for about 10°."	Sparks remained visible some time after the body had vanished.
30	6 30 p.m.	Passed near ♀	About = ♀ ...	No explosion, train, or sparks.	....
Nov. 9	3 0 a.m.	Six meteors within an hour of each other.	Bright yellowish.	Sparks: no explosion......	Appeared 30° from zenith & moved. About same time on other nights many meteors.

Various Observers.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
In the S. at low altitude, descended from S. to E.	....	East Knoyle, Wilts.	A correspondent to Lord Wrottesley.	MS. communication from Lord Wrottesley.
Nearly S.	All the accounts nearly similar.	Blackheath, Southampton, Brighton, River Hill near Sevenoaks.	Mr. J. Rogers, Mr. T. Kimber, and Correspondents to several Journals.	See Appendix No. 2.
From S. to W. parallel to horizon. Altitude 40°; passed near ♃.	....	Wrottesley Observatory, Wolverhampton.	Observatory Assistant.	MS. communication from Lord Wrottesley.
From E. to N. at inclination of 40° to horizon.	Rain at the time ...	Ibid.	Id.	Ibid.
Nearly S., vanished within 30′ of ♃.	♃ barely visible from clouds.	Ibid.	Id.	Ibid.
....	....	Ibid.	Id.	Ibid.
In the N., all at small altitudes midway below Ursa Major and Cassiopeia; directions nearly horizontal but inclined towards W.; one inclined nearly at 45°. All moved from E. to W.	Sky partially clouded.	Margate	Prof. Powell and Mrs. Powell.	
Just below Ursa Major, forming an equilateral Δ with β and γ. From W. to E. about 3°.	....	Tavistock Place, London.	F. V. Fasel, Esq.	MS. communication.
From N. to S.; disappeared near the Pleiades.	....	Tavistock Place, London.	Id.	Ibid.
From S.E. to N.W., from α Persei to ε Ursa Major. Straight course.	....	Oxford	Mr. G. A. Rowell.	Ibid.
....	....	Bombay.	A Correspondent to Bombay Times.	Bombay Times, Nov. 1.
Altitude 25° in N.E., moved through 30° upwards.	....	Bombay	Id.	Ibid.
From a little N. of zenith towards S.E., disappeared at 20° alt.	....	Kandallah	Id.	Ibid. Nov. 6.
3 to S.E., 3 to N.W.	....	Bombay	Id.	Ibid. Nov. 11.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1856.	h m				
Nov. 28	11 45 p.m.	Several shooting stars. One remarkable.	One very bright; illuminated objects around "like a flash of lightning."	Bright train from a few degrees from the zenith to about a degree W. of ♄, seen after the meteor had disappeared; remained a few seconds.	....
1857.					
Feb. 9	9 35 p.m. (G.M.T.)	= ♂	Bluish white. Intensely bright and sparkling.	Left a whitish serpentine train for an inappreciable instant.	Less than 1 sec. ...

Luminous Meteors observed in 1855–56–57, by J. King Watts,

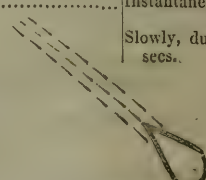
1855.					
Oct. 6	11 3 p.m.	Large	White	No sparks	Slow..................
Nov. 30	7 0 p.m.	= 1st mag.*............	White	....	Slow..................
Dec. 6	7 15 p.m.	= 2nd mag.*	White	Sparks	Slow..................
	10 45 p.m.	Small	....	No sparks	Rapid ....
1856.					
Aug. 25	10 46 p.m.	Large	Reddish	Sparks .... 	Slow..................
Oct. 21	7 16 p.m.	= 1st mag.*............	White	Many sparks and long train.	Slow..................
27	7 6 p.m.	= 2nd mag.*	White	Many sparks	Quick ....
	8 25 p.m.	Large	Bluish-red ...	Long train and sparks after it had become invisible. 	Rather slow.........
	10 46 p.m.	Small	White	None	Rapid ....
Nov. 5	7 58 p.m.	....	White	....	Rapid ....
18	7 30 p.m.	Very large	Red with purplish tint.	Sparks	Slow..................
27	10 36 p.m.	Small	White	....	Quick ....
Dec. 20	9 45 p.m.	= 2nd mag.*	White	....	Quick ....
1857.					
May 14	10 15 p.m.	Large	White	No sparks	Slow..................
July 20	11 5 p.m.	Large meteor	White	....	Rather slow.........

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
....	....	A little N. of Whittington, near Oswestry.	Rev. A. R. Lloyd.	MS. communication.
Moved vertically downwards through about 8°; disappeared 20° W. of Sirius.	Light clouds concealed everything except Sirius.	Near Glasgow ...	W. J. Macquorn Rankine, Esq., C.E.	MS. communication.

Esq., F.R.G.S., F.E.S., St. Ives, Huntingdonshire.

From E. to W.......................	....	St. Ives, Hunts..	J. King Watts.	
From N. to S.......................	A beautiful object..	Ibid................	Id.	
From α Ursa Major to Pleiades	....	Ibid................	Id.	
....	....	Ibid................	Id.	
From α Cygnus passing α Lyræ to the W.	Had a very beautiful appearance with a long whitish-red line running from it, emitting sparks.	Ibid................	Id.	
From Draco to Pegasus	Emitted a strong light.	Ibid................	Id.	
From Ursa Major to Ursa Minor	....	Ibid................	Id.	
From Polaris to α Cygnus	A very bright and brilliant meteor, leaving a strong light.	Ibid................	Id.	
From Cepheus to Westward ...	....	Ibid................	Id.	
From α Andromedæ towards Cygnus.	Had the appearance of a strong flash.	Ibid................	Id.	
From Cassiopeia to α Lyræ ...	Unusual brilliancy, and was very startling.	Ibid................	Id.	
From Pleiades to α Persei	....	Ibid................	Id.	
From α Aries towards Pegasus..	....	Ibid................	Id.	
Fell from α Andromedæ down towards the W.	Bright	Ibid................	Id.	
From Ursa Minor down towards Camelopardalis.	Very bright. It rose in sight suddenly and very brilliant, remained stationary for upwards of 5 minutes, then slowly passed downwards.	Ibid................	Id.	

Meteors observed by

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1856. Aug. 2	h m 12 4 a.m.	=1st mag.*	=1st mag.* red.	None	Slow, duration 1 sec.
	12 10 a.m.	=2nd mag.*	Colourless	Streaks	Rapid
5	9 0 p.m.	=3rd mag.*	Colourless	Streak	Rapid, duration 0·1 sec.
31	8 55 p.m.	= $\frac{2}{3}$ size ☾	Reddish yellow 	No train	2 sec.
	9 15 p.m.	=3rd mag.*	...	Streak	Rapid
	9 31 p.m.	=2nd mag.*	Blue	Streak	0·3 sec.
	9 37 p.m.	=8th mag.*	...	...	...
Oct. 18	9 22 p.m.	2nd size 1st mag.*	Yellowish	Streak	1½ sec., slow
21	...	...	...	...	...
28	large meteor	...	...	...	...
31	9 p.m. till 10 p.m.	Six meteors above 3rd mag.*	All colourless.	All streaks	Exceedingly rapid.
Nov. 20	7 40 p.m.	=2nd mag.*	Colourless	Streak	Rapid
	9 0 p.m.	Very small	...	...	...
Dec. 20	...	...	...	...	...
9	2 20 a.m.	=2nd mag.*	Yellowish	Streak	Instantaneous
13	7 18 30 p.m.	Larger than Saturn	Yellowish	Train ... 	Slowly, duration 2 secs.
18	8 19 p.m.	2nd mag.*	Colourless	Streak	Not rapid
	8 54 p.m.	2nd mag.*	Colourless	Streak	Moderate
20	8 10 p.m.	2nd mag.*	Yellowish	Train	Rapid
	9 7 30 p.m.	2nd mag.*	Yellowish	Train	Tolerably rapid, duration 0·3 sec.
1857. Jan. 9	11 15 p.m.	Large	Bluish	Yellow tail	...

E. J. Lowe, Esq.

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Moved horizontally immediately under Aries and only 4° above the horizon.	Circular	Highfield House.	E. J. Lowe	Mr. Lowe's MS.
Fell down from *o* Ursæ Majoris	Two meteors close together.	Ibid................	Id.	Ibid.
Fell from direction of Polaris towards Capella.	....	Ibid................	Id.	Ibid.
Started at *μ* Ophiuchi, and passed midway between *ν* Serpentis and *ζ* Ophiuchi, passing across No. 52 Serpentis and fading 3° lower.	Rapidly increased, without altering its form, from 3rd mag.* to ⅔ size of ☾, and suddenly vanishing when at its maximum brightness.	Ibid................	Id.	Ibid.
Moved exactly in the same path as the last.	....	Ibid................	Id.	Ibid.
From *η* Ursæ Majoris towards W. horizon at an angle of 50°.	....	Ibid................	Id.	Ibid.
From No. 13 Delphini almost perpendic. down.	Seemed very near the earth.	Ibid................	Id.	Ibid.
From about *α* Cygni passing 5° N. of Altair.	Moonlight	Beeston	Id.	Ibid.
....	Many meteors	Ibid................	Id.	Ibid.
....	....	Ibid................	Id.	Ibid.
All perpendic. down	Many meteors, mostly in Ursa Major, Ursa Minor, and Draco.	Ibid................	Id.	Ibid.
Fell perpendic. down from ½ between Capella and *ι* Aurigæ.	....	Ibid................	Id.	Ibid.
Same path as the last...........	....	Ibid................	Id.	Ibid.
....	Several meteors ...	Ibid................	Id.	Ibid.
Fell down and ending at *η* Ursæ Minoris.	....	Ibid................	Id.	Ibid.
From *β* Aurigæ down at an angle of 45° towards N., fading away 8° immediately above ☾	Kite-shaped, and had many streaks left which lingered and seemed to ignite after the meteor had passed by. Moved behind several cirri.	Ibid................	Id.	Ibid.
Perpendic. down from *β* Cygni	....	Ibid................	Id.	Ibid.
Down from *ε* Aurigæ	....	Ibid................	Id.	Ibid.
From *α* Andromedæ up towards zenith.	Stars very bright and scintillating considerably.	Ibid................	Id.	Ibid.
From *α* Draconis downwards at an angle of 50° towards W.	....	Ibid................	Id.	Ibid.
In S.E.....................................	Moon bright, but her light was nothing whilst the meteor lasted	Broomfield House, near Ashford, Wicklow.	F. Wakefield, Esq.	Ibid.

Date.	Hour.	Appearance and Magnitude.	Brightness and Colour.	Train or Sparks.	Velocity or Duration.
1857. Feb. 26	h m 8 12 p.m.	=1st mag.*…………	Bluish ………	Train ………………………	Rapid, duration 0·3 sec.
	11 3 p.m.	=3rd mag.* ………	………………	Streak ………………………	Rapid ……………
April 16	11 36 p.m.	8 times size of ♃ …	Colourless …	Leaving a long train of light for several seconds.	Slowly ……………
¶Aug. 9	8 30 p.m.	=1st mag.*…………	Colourless …	Streak ………………………	Slowly ……………
13	10 30 p.m.	=♃ …………………	Colour steel-blue.	Small tail…………………	Slow, duration 5 to 6 secs.

¶ The August meteors have been badly seen here, owing to much cloud on the one hand, and full cricket-ball, fell N. of Nottingham. It is probably a meteor, and has been promised to me: the person

APPENDIX.

No. 1.—Details of a Meteorite mentioned in a former Report, which fell at Cirencester in 1835. Extract of a letter to Prof. Powell from Thos. C. Brown, Esq.

"Copy of a notice of the Meteorite entered in the Book of Donations of the Permanent Library, Cirencester, by the late Mr. Arnold Merrick, Curator to the Museum.—'A specimen of a meteorite which fell about half a mile from Aldsworth in a field occupied by Mr. Waine, within twenty yards of his workmen, who were sitting against a wall at the time, on the 4th of August 1835, a sunny afternoon without a cloud. A meteor was seen at Cirencester proceeding eastward, and a remarkable noise was heard at half-past 4 in the afternoon. The noise was heard in most parts adjacent.

"'The workmen saw no unusual light, but heard the aërolite rush through the air, and felt it shake the ground by striking it with great violence. It fell on a swarth of oats, and drove the straw before it down into the earth for six inches, till opposed by rock. When the men got it up, it was not hot, but the part of the surface which appeared not to have been broken was quite black and soiled the fingers. It weighs about 9270 grains. It contains a great deal of iron, but is not magnetic. Its specific gravity is 3·4.

"'Mr. Waine states that a shower of small pieces fell about half a mile south of the spot where this fell. Children thought it was a shower of black beetles, and held out their hands to catch them as they fell.'

"My niece, Miss Anna Sophia Brown, now Mrs. Pooley, about 4 P.M. on the same day, being in her father's garden at Cirencester, perceived a meteor passing from W. to E., apparently about twice the height of Cirencester tower, which is upwards of 100 feet high, looking like a copper ball larger than an orange [?], and having a tail or stream of light behind it. In its passage it made a rumbling noise heard by many persons, reminding her of thunder, and the people of the town marvelled that it should thunder in a serene day with a cloudless sky. On the same day at Aldsworth, 13 miles E. of Cirencester, the meteoric stone fell, the particulars of which are before given. "THOS. C. BROWN."

No. 2.—From the *Express*, Wednesday, January 9, 1856.

Remarkable Meteor.—A correspondent writes, under date Southampton, January 8, 1856:—"The meteor observed here yesterday made its appear-

Direction or Altitude.	General remarks.	Place.	Observer.	Reference.
Nearly perpendic. down, inclining to W., and passing through Polaris.	Aurora Borealis ...	Beeston	E. J. Lowe	Ibid.
Downwards from S. of Saturn..	....	Ibid................	Id.	Ibid.
From η Ursæ Majoris to 10° below the nebula in Andromedæ.	....	Highfield House.	Capt. A. S. H. Lowe.	Ibid.
In N.E. near horizon............	....	Beeston	Mrs. E. J. Lowe.	Ibid.
Fell from the S.E. towards the W.	Sky clear, after much thunder and rain.	Broomfield House, near Ashford, Wicklow.	F. Wakefield, Esq.	Ibid.

moon on the other.—On Aug. 13th, a ball as smooth and round as a billiard-ball, and larger than a who found it concluded it was a thunderbolt.—E. J. Lowe.

ance during twilight. It descended perpendicularly. The light which heralded the fire-ball was at first not unlike the streak of brilliant sparks that precedes the bursting of a sky-rocket. The fire-ball likewise originated apparently very much as the fire-balls of a sky-rocket originate, from some explosive and combustible agency. But the light after the discharge of the fire-ball became gradually whiter, and persons who looked at it through a telescope saw shining in its centre what appeared like a star. The shape of the streak or band of light was not unlike the blade of a huge flaming sword suspended in the heavens with the flat surface towards the north. That its substance was remarkably dense and firm is evident, since its shape was unaltered and its edges were sharply defined for more than five minutes. In fact, so stable did it appear in the heavens, that numbers of people were overcome with wonder and dismay, and shed tears. After a time it became more cloud-like and tenuous; its edges gave out, and its straight and perpendicular direction became less firm. At one time its colour was not unlike the very white steam forced from a boiler, and it assumed a serpentine form. Before it vanished, however, it was cloud-like in its appearance and movements. A few stars were visible in the heavens when the meteor appeared."

A paragraph in the *Brighton Examiner* shows that the remarkable meteor above described was visible in that town:—

"About five o'clock on Monday evening a very brilliant and extraordinary meteor was observed by several of the inhabitants over the sea in a south-easterly direction. The ball, apparently of fire, was exceedingly splendid, leaving a brilliant ribbon, as it were, behind it, as bright as molten silver. It fell nearly perpendicularly, the ribbon assuming a spiral form, till it finally vanished, in about ten minutes after its first appearance. The sky at the time was beautifully clear and cloudless. When first seen it was considerably more than 45 degrees in height, and extended 10 or 12 degrees."

Another Account.—"A very beautiful meteoric phænomenon was observed in the S.S.W. part of the heavens this evening just after five o'clock. My attention was first arrested by the appearance of a very brilliant light darting suddenly towards the earth, apparently proceeding from a star, which, I think, is the planet Jupiter, at present an evening star, taking an easterly direction. My first impression was that an immense sky-rocket had been discharged into the air, but instead of the train of fire proceeding upwards, it rapidly descended towards the earth, or rather the Channel, for it must have been several miles from land; and as it extended in length, lost some

portion of its brilliancy and became nearly stationary. At first the appearance was like a long oblique line of fire, which gradually swelled out towards the centre, and curved itself not unlike a huge gilded serpent. Its apparent length was between 20 and 25 feet[?]. The phænomenon was visible about fifteen minutes—becoming more attenuated, and at length entirely dissipated or diffused in the atmosphere."—*Brighton Examiner.*

"*To the Editor of the Times.*

"Sir,—Having just witnessed a very remarkable meteor, I hasten to send you the particulars of it as observed from this place. At nine minutes to 5 (4·51 P.M., or, perhaps, $4^h\ 51^m\ 30^s$) a brilliant ball of white light fell from a point in the S.S.W., 3° or 4° south and east of Jupiter. It grew brighter as it fell, but did not appear to burst, and vanished about 12° from the horizon; its course was nearly perpendicular, but slightly inclined to the east. It left behind it a brilliant streak of white light, tapering to both ends, about 6° in length, which immediately assumed a curved or spiral form, exceedingly like a serpent rearing itself up. The middle part of this tapering band of light gradually expanded, taking the form of small fleckering clouds (*cirro-cumuli*). This became gradually more curved, or rather spiral, and the whole mass drifted very slowly towards the south-east, the middle part having apparently a more rapid motion than the extremities. It continued distinctly visible for upwards of 10 minutes, when some heavy mist clouds drifting up from the north-east obscured it. Being near the house, I got out an astronomical telescope with a glass of low power, but was unable to decide whether the light seen was vapour in the atmosphere (which it much resembled), or diffused nebulous light.

"The sky at the time the meteor appeared was perfectly clear and bright with the rays of twilight. Its size was somewhat difficult to estimate, but I should guess it at about four times the apparent diameter of Jupiter, which was close at hand.

"Whatever wind there was came from E.N.E., but there were no clouds in the upper sky to indicate the direction of currents there. Not the slightest sound was perceptible. The point at which it first became visible was, as nearly as possible, 20° above the horizon, ascertained by an altitude circle. I had not time to get out an azimuth instrument to verify its position in azimuth; but the foregoing particulars may be useful for comparison, as it has, doubtless, been observed in many places.

"I am, Sir, yours faithfully,

"River-hill, Sevenoaks, Jan. 8, 5·15 P.M." "John Rogers."

"*To the Editor of the Times.*

"Sir,—Nearly due south a meteor of a most remarkable and brilliant character was observed this evening. The sky was clear overhead, but not bright, and there arose from the horizon, to the height of about 10°, black and jagged clouds. A falling star was said to have been first seen, and immediately afterwards the writer had an uninterrupted view of the meteor, which at first seemed to emerge from the dark clouds in a strictly vertical direction, and stretched at least to a height of 30° from the horizon. In form its first appearance was that of a wand, and it gradually tapered at the ends and expanded in the middle, at which time its appearance was most brilliant, its edges distinct and smooth; and it was of such intense whiteness as to seem an opake body, though bright as the new moon. As the expansion at the centre increased, the ends were bent in contrary directions, and Hogarth's 'line of beauty' was inscribed in the heavens on a gigantic scale.

"After a short time the meteor seemed to be broken at regular intervals,

and it had then the appearance of dislocated vertebræ. At this time the light was deep yellow, inclined to red,—probably a reflection from the sun, not far below the horizon. Its edges at last lost their character, its light became pale, and very gradually it vanished altogether without the slightest noise of any kind, which was attentively listened for. From its first being noticed to its final disappearance, a period of about ten minutes elapsed. All the changes seemed to be produced slowly, and only in its sudden appearance had it at all the character of a gaseous explosion.

"I remain, Sir, your obedient servant,

"Blackheath, Jan. 7, 4·50 P.M." "T. KIMBER."

No. 3.—A paper "On the Horary Variation of Meteors," by G. C. Bompas, Esq., was communicated to the Royal Astronomical Society, and of which an abstract appears in their Notices for March 1857, p. 147.

These researches relate to the law, and to the probable cause, of the *horary variation* in the number of meteors, established by the observations of Coulvier-Gravier, Saigey, and others. (Recherches sur les Étoiles Filantes, Paris, 1845, and Humboldt's Cosmos, iii. 440.)

From these various researches the following table gives a summary of the number of meteors at different hours of the night:—

Hours P.M.	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12
Mean No. of Meteors...	3·3	3·5	3·7	4	4·5	5

Hours A.M.	12 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6
Mean No. of Meteors...	5·8	6·4	7·1	7·8	8	8·2

It thus appears that from 6 P.M. through the night to 6 A.M., the number of meteors *seen* regularly increases. But it is assumed that this is a fair representation of the number *actually* occurring, or which would be seen, if daylight permitted, in those hours of which no mention is made in the observations, a circumstance which may be open to question.

Again, if we estimate the numbers observed as coming from *different quarters* of the heavens, designating the numbers which come from the several points of the compass by those initials respectively, then the average of the observations gives—

E. greater than 2 W.
N.=S. nearly,
but E.+W.=N.+S.

Coulvier-Gravier observes, "But for *the cause* which transfers from the West to the East nearly one-half the number due to each of these directions, there would come exactly the same numbers of shooting stars from the four points of the compass."

He does not, however, appear to assign what that cause is.

As to the *heights* of meteors, it appears that the greatest heights which have been ascertained bear but a very small proportion to the earth's radius. The altitudes of the greatest number lie between 16 and 140 miles, though some reach 200 or 400 miles. (See Herschel's Outlines, 904.)

The *velocities* of meteors have been variously assigned as from 18 to 36 miles per second; but some have been 90 miles. (Herschel, *ibid.*)

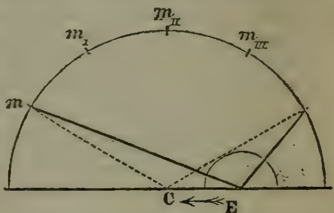
Boguslawski considers that 5 out of 6 have a velocity about double that

of the earth in its orbit, which he takes as a fair average. (Étoiles Filantes, p. 102.)

Mr. Bompas observes, that, as already seen, the observations indicate a maximum of meteors at 6 A.M., and a minimum at 6 P.M.; he also adverts to the fact, that the part of the heavens towards which the earth is moving at any time is always 90° or 6^h from the direction of the sun. Thus at 6 A.M. the observer's meridian is in the direction of the earth's motion, and at 6 P.M. in the opposite. In other words, the law is this: that *the greatest number* of meteors is encountered when *the observer's meridian is in the direction of the earth's motion*, and the number diminishes thence regularly to 6 P.M., when he looks the opposite way.

Combining these considerations the author explains the facts on a very simple principle, expressed by a construction of which the *essential* points are here represented.

m, m_1, &c. being meteors *equally* distributed in space would converge to the earth at C if at rest, *equally on all sides*. But if the earth move in the direction ⟵EC with a velocity *half* that of the average velocity of the meteors, they will converge to the earth at E half-way from the extremity to the centre; and thus two-thirds nearly will fall on the side towards C, or would have an apparent motion more or less opposed to that of the earth, and diverging from the point towards which the earth is moving.



The author gives this only as a *general* explanation of the principle. He admits that the exact amount is more difficult to determine, and will chiefly depend on the proper velocity of meteors, which seems at present not well ascertained, and on their average direction, if ascertainable. It will also be materially affected (as he points out) by the inclination of the earth's axis; but these points remain for further investigation.

No. 4.—"On the Colours of Luminous Meteors," by M. A. Poey, Director of the Physical and Meteorological Observatory at Havannah.

(From the Comptes Rendus, vols. xliii. and xliv.)

The author observes, that, being much interested in the differences of *colour* of luminous meteors, he has drawn up three tables, one of which comprehends all the shooting stars and globes recorded as observed in China, the second those observed in England (including some other countries), and the third those at Paris. For the first table, he has made use of the well-known catalogue by Edouard Biot * of the shooting stars and globes observed in China during 24 centuries, since the 7th century before Christ to the middle of the 17th of our era. For the second table, he has had recourse to catalogues published annually in England, from 1841 to 1855, by Prof. Baden Powell, in the Reports of the British Association for the Advancement of Science. Lastly, for the third table, he has used the catalogue of shooting globes observed at Paris, from 1841 to 1853, by M. Coulvier-Gravier. Thus these three tables together comprise 2145 cases of coloured shooting stars and globes observed in these several localities. With respect to *coloured* shooting stars and globes, he has found nothing in the catalogues of Messrs. Quetelet, Herrick, Chasles and Perry. In the three tables is given the monthly distribution of the different colour of shooting

* Mémoires des Savants Etrangers, vol. x. pp. 129 and 415.

stars and globes. This notice appears to the author important, both as regards atmospherical optics, and the relative dependences which may exist between particular colours and the appearances or modifications of other meteorological phænomena, as well as the variations of time according to the seasons.

(1) Colours of shooting stars and globes observed in China from the 7th Century B.C. to the 17th A.D.

(Comptes Rendus, vol. xliii., Dec. 15, 1856.)

Colour.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Red	2	2	2	4	2	2	8	6	6	5	5	7	51
Whitish red	0	0	0	1	1	0	1	0	0	1	1	0	5
Yellowish red ...	22	27	31	25	24	30	84	53	48	80	64	37	525
Yellow	0	0	0	1	0	0	0	2	0	1	2	0	6
Whitish yellow ...	0	2	0	1	0	0	1	0	0	0	1	0	5
Reddish yellow ...	2	4	4	0	3	4	5	3	3	7	5	2	42
Blue	1	0	0	0	0	0	1	0	1	1	0	1	5
Whitish blue	11	10	12	14	33	17	35	32	39	49	42	11	305
Bluish white	1	1	1	2	1	2	3	2	0	4	0	3	20
Reddish blue	0	1	0	0	3	1	1	0	1	1	0	1	9
Blackish blue ...	0	1	0	1	0	0	0	0	0	0	1	0	3
White	0	0	1	2	1	1	2	3	4	2	1	1	18
Total ...	......	......	......	......	......	......	......	......	......	......	......	......	994

There is also one case of a bluish-red meteor, one of a bluish one, one of blue and white, one of yellow and blue, two of whitish, and one of the colour of a stork's feather. Total 1004 shooting stars and globes observed in China in the space of 24 centuries.

In the above table, it appears that the primitive or simple colours are as rare as the compound colours are numerous; such as the yellowish red and the whitish blue. This result is contrary to that which we obtain from the table of observations made in England, where, out of a total of 1065 coloured meteors, 326 are of a pure blue, 151 of a pure yellow, and 129 of a pure red.

It is an important fact, that in the 1004 meteors observed in China during so long a period as 24 centuries, we do not find a single indication of a green shooting star or globe. This circumstance is the more remarkable, since a scientific English observer, Dr. Buist, had already stated in 1849, that the finest meteors resembling a star of the first magnitude, which are observed in India, are generally of an orange, bluish, or greenish colour. In the above table of the 24 centuries of observations in China, the colours orange and greenish are entirely wanting. However, in the 1065 meteors observed in England, there are 78 of a pure orange colour, and 33 cases of colours compounded with orange. Then there are 5 meteors of a pure green, and 8 cases compounded with green. In the catalogue of M. Coulvier-Gravier, of 76 coloured shooting globes, we observe 8 cases of green globes, and 4 of globes which broke up into green-coloured fragments.

(2) Colours of shooting stars and globes observed in England from 1841 to 1855.

(From the Comptes Rendus, *ibid.* Dec. 29, 1856.)

In the observations made in China given in the preceding table, the author

observes one peculiarity as deserving of notice:—viz. that the number and constancy of the same tints in the observations of one period or dynasty differ from those whether in the preceding or succeeding period. The same, he says, holds good with respect to the colours observed when meteors explode, whether breaking up into fragments or not.

In making his inferences from the titles of observations in China as well as of those in England and Paris, the author excludes those cases where the body of the meteor and its train exhibit *complementary tints*, like some of the double stars: this relation of tints he also finds in many cases of meteors which break up into *fragments* as compared with the original colour; and in meteors simultaneously accompanied by others, as well as in the coloured light sometimes projected by them on the earth. He also observes that the colour often changes in the course of a meteor through the atmosphere, from *white* near the *zenith* to *blue* near the horizon. He also excludes from his comparisons those meteors which have trains of the same colour with the body.

Colours of meteors observed in England from 1841 to 1855 (including some in other parts of the world).

Colour.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Red	5	6	2	4	3	5	14	36	14	15	20	5	129
Reddish	1	1	4	0	0	0	6	13	14	4	4	1	48
Orange	0	2	3	1	0	1	1	4	31	16	16	3	78
Orange-red	0	1	0	2	1	0	1	4	5	3	7	5	29
Yellow	4	6	1	2	5	5	23	39	33	16	14	3	151
Yellowish	0	1	1	0	1	0	0	5	5	3	2	0	18
Green	0	1	2	0	0	1	1	0	0	0	0	0	5
Greenish	0	1	1	0	0	0	1	0	1	0	0	0	4
Blue	3	6	3	17	2	4	31	138	56	36	26	4	326
Bluish	0	0	0	1	1	0	4	23	10	4	3	0	46
Whitish blue	0	1	1	0	1	0	3	3	1	0	1	0	11
White	1	3	6	6	7	2	11	45	34	26	15	2	158
Whitish	0	0	0	0	0	0	0	1	2	1	2	1	7
Diamond	0	0	0	0	0	0	2	1	1	1	1	0	6
Uncoloured	3	0	0	1	1	0	5	2	11	0	0	1	24
Total	......	......	......	......	......	......	......	......	......	......	......	......	1040

Besides the coloured shooting stars and globes indicated in the above table, there are also the following:—reddish white, 3 cases in April, June, and August; orange-yellow, 2 cases in September and December; slightly orange tinged with white, 1 case in June; yellowish red, 1 case in December; greenish white, 2 cases in November and December; greenish blue, 1 case in December; purple and green, 1 case in May; reddish blue, 2 cases in April and November; violet, 1 case in February; pale rose-coloured, 1 case in November; purple, 2 cases in August and November; yellow and violet, 1 case in September; orange and prismatic, 1 case in November; coloured, 2 cases in January and November; dull-coloured, 1 case in September; brown, 1 case in September; yellowish white, 1 case in July; brilliant white tinged with brown and silver, 1 case in August. Total 1065 coloured shooting stars and globes principally observed in England from 1840 to 1855.

We see in the above table that the simple or primitive colours most

predominate, and that the compound blue-coloured meteors are twice as numerous as those of a pure yellow and red colour ; a result contrary to that obtained from the preceding observations in China. We observe that the meteors comprised in the tints belonging to the lower part of the spectrum, from green to red, are in number 465 cases, while those comprised in the tints of the upper part of the spectrum, from green to violet, embrace 401 cases. Now, in applying to the colouring of shooting stars and globes the theory of M. Charles Doppler on the colour of single fixed stars, of the double stars, and stars periodically variable, it would be necessary to conclude from the facts, that 64 coloured meteors have been moving *from* the observer, from the moment of their appearance ; supposing, which is not always the case, that the meteors have followed the right line which joins them with the eye of the observer. However, on the other hand, meteors of a pure blue, which are of an ascending tint and approach towards the observer, are twice as numerous as those of a pure red and yellow, which belong to the descending tints and recede from the observer. According to the theory of M. Doppler on the colour of fixed stars, an object luminous by itself, or from a borrowed light, increases in intensity as it approaches the observer, while the colour passes, rapidly ascending from white to green, then to blue, and at last to violet. By receding, the intensity diminishes in all cases, and the white light passes successively to yellow, to orange, and at last to red. Perhaps we ought still to take account, in the colour of fixed and shooting stars, of the differences of perception and appreciation of luminosity and colour, of different observers.

(3) Colours of shooting stars and globes observed at Paris from 1841 to 1843, with notices of trains, fragments, &c., differently coloured, observed in China as well as in England.

(From the Comptes Rendus, xliv., Jan. 12, 1857.)

The author now proceeds to give a list of coloured shooting globes observed at Paris from 1841 to 1853 by M. Coulvier-Gravier*. This skilful observer has given with great precision as many as three or even four successive shades assumed by meteors in their transit through the air. These tints almost entirely follow the law deduced by M. Doppler†, on the variation of colour of a luminous point in motion. The greater part of the shooting globes appear *blue* on *approaching* the horizon or the observer, after having passed through all the tints corresponding to the upper part of the spectrum. Some terminate with *red*, probably in *receding* from the observer. Besides the law of M. Doppler, which may be applied to the colours of meteors, we ought still to take account of the particular state of the atmosphere in a twofold point of view, as regards electro-chemistry and the modificators of meteorological agents.

Colours of globe meteors observed at Paris from 1841 to 1843.

January.—Bluish ; bluish towards the horizon, 2 cases.

February.—Bluish ; bluish towards the horizon, 2 cases ; fragments yellow, red, then greenish-yellow globe, and three fragments bluish towards the horizon.

March.—Yellow-orange, then green ; bluish towards the horizon.

April.—Bluish towards the horizon ; white, orange-yellow, orange, then blue-green.

May.—Bluish towards the horizon ; white, then bluish towards the horizon ; clear yellow, then bluish ; clear yellow, then yellow-orange.

* Annales de Chimie et de Physique, vol. xl. (January 1854).

† Répertoire d'Optique Moderne de M. l'Abbé Moigno, 3rd part, p. 1165–1203.

June.—A little bluish; bluish; reddish towards the horizon; yellow; greenish towards the horizon.

July.—Bluish towards the horizon, 4 cases; very white, then bluish towards the horizon; yellow, green, blue, then red; fragments greenish yellow, bluish, then reddish; fragments clear yellow, then yellow-red.

August.—Reddish, 2 cases; bluish; bluish towards the horizon, 6 cases; whitish, then blue towards the horizon; whitish, then bluish; very white; broke itself into bluish fragments near the horizon.

September.—Bluish; bluish towards the horizon, 4 cases; copper-red, then bluish towards the horizon; yellow-red; then bluish; reddish, bluish, then greenish blue, as also the fragments.

October.—Red towards the horizon; bluish; bluish, red, then greenish; brilliant yellow, then yellow-red; copper-red, white, then greenish at the horizon; yellow, bluish yellow, then reddish; clear yellow, then copper-red.

November.—Bluish, 2 cases; bluish towards the horizon, 2 cases; fragments bluish; yellow-orange towards the horizon; fragments yellow, red, greenish blue; yellow-white, yellow-orange, then greenish, very white, being broken into fragments; two only passed from white to the colour of red-hot iron; reddish.

December.—Reddish towards the horizon; bluish towards the horizon, 2 cases; bluish; copper-yellow; yellow, then bluish towards the horizon; whitish, then blood-red.

Total of coloured shooting globes, 76 cases.

Globes with trains differently coloured from the body.

July.—Globe bluish towards the horizon, with a deep red train; white, then bluish, with a remarkable red-white train; white, reddish, then bluish towards the horizon with reddish train.

August.—Globe bluish towards the horizon with greenish train.

September.—Globe very brilliant white, with train reddish on the west side, greenish in the middle, and whitish on the east side.

Total of globes with different-coloured trains, 5 cases.

Globes with trains similarly coloured.

July.—Greenish train.

August.—Bluish trains, 3 cases; greenish train.

September.—Clear yellow train, then deep red.

October.—Very white train, then at the end of its duration of a less splendid whiteness.

November.—Reddish trains, then greenish, 2 cases.

December.—Reddish train, bluish, then greenish.

Total of globes with uniquely-coloured trains, 10 cases.

The author states that these meteors correspond to the period of the observations made in China and in England described in the preceding notices.

Changes of colour.

In China.—April: colour of fire, then white. December: red, then white.

In England.—February: green, red, then violet; globe green, red, then violet. April: red, then blue, 2 cases. July: brilliant orange-red, almost white, then very brilliant red. August: reddish, then brilliant blue. September: straw colour, then purple. November: orange, then orange-yellow, pale orange, and after 15° of transit, bluish.

Shooting stars accompanied by coloured tails of the same tints.

In China.—November: red star, divided itself into 5 stars, of which the first had a red tail.

In England.—August: blue star, bluish train; stars accompanied by trains differently coloured.

In China.—June: a star (with a train) 200° in length; had the front part black, the termination red, and the middle white.

In England.—February: a brilliant red star surrounded with the tints of the rainbow, with a bluish train. March: red star, train blue. April: star surrounded by a rich colour of purple, then blue, orange, and clear yellow; considerable train, clear yellow. July: cream-coloured, train purplish red in the centre and greenish blue at the latter part; blue star, train of pale red sparks. August: bluish white, train red. September: orange, train red; brilliant white, reddish train; blue, then brilliant red, throwing out sparks leaving a blue mark, visible during several seconds.

Shooting stars with similarly coloured trains.

In China.—Trains yellowish red: June, July, August, and November, 2 cases each; October and September, 1 case. Yellow: January, 1 case. Reddish yellow: May and October, 1 case. Whitish blue: August and October, 2 cases; February, April, May, November, and December, 1 case. Reddish blue: June, 1 case. Blue and yellow: October, 1 case.

In England.—Red: July, 1 case. Reddish: August, 1 case. Blue: February, April, and December, 1 case each; August, 2 cases. Bluish: November, 1 case. Of different colours: February, 1 case. With train of pale brilliant sparks: June, 1 case.

Change of colour of stars when they break into fragments.

In China the star divided itself into 1 blue and 2 red stars; at the moment when a globe of fire fell, a flame appeared, and a score of little red stars spouted out of it. This case, marked by M. Abel Résumat, is not noticed by M. Biot.

In England.—March: green star, fragments red; white star, gave greenish and red flashes in exploding. April: bluish red, fragments prismatic; star blue at the moment of explosion. July: yellow or pale orange star, three dull red fragments. October: brilliant globe separated into fragments with several colours.

Shooting stars accompanied by others differently coloured.

In China.—Winter and October: one red, the other white, 2 cases. November: one yellow, the other red.

In England.—July: fine orange-red globe, followed by a multitude of little blue globes, afterwards purple.

Stars with *reflexions* of a different colour.

In China.—July: blue star threw out a reddish light which illuminated the earth. December: reddish-blue star, *ibid.*; bluish light.

Various other effects.

In China.—October: red star, whose tail changed itself into a bluish-white vapour. May: a train dispersed itself slowly and became a greenish-black cloud. A tail divided itself into little whitish-blue stars.

No. 5.—"A Memoir on Meteorites: and Description of five new Meteoric Irons," &c., from the American Journal of Science, May 1855, vol. xix., by J. Lawrance Smith, M.D., Professor of Chemistry in the University of Louisville, U.S.

In this communication the author describes in detail specimens of meteorites found in North America—2 in Tennessee and 3 in Mexico. Figures are given representing their general appearance, and chemical analyses of

their composition. It does not appear that any of them were seen to fall, or known to have been accompanied by any meteoric appearances, except in one instance, in which a very vague tradition of this kind is mentioned. He notices their irregular and fragmentary form and crystalline structure, which he conceives evince the agency of intense heat, and show them to be fragments of larger bodies.

The presence of metallic iron in so large a proportion as that in which it is found with respect to the other ingredients, he conceives to indicate a proof of the absence of oxygen (in its gaseous state, or in that of water) in the body from which the fragments are derived.

The stony portions of the meteorites resemble exactly volcanic products; in which the presence of iron also furnishes a point of analogy. He also comments on the usual presence of phosphorus, which is derived from the mineral Schreibersite, constantly occurring in these masses. The metallic nickel, cobalt and phosphorus show equally the absence of oxygen. Carbon is often found, contrary to the assertion of some observers.

The Schreibersite, which is observed as almost constantly present, the author remarks, is wholly *peculiar* to *meteorites*; no *natural* phosphuret of iron, nickel, or other metal being found as a terrestrial mineral.

Hence he considers meteorites as having a common origin exterior to the earth, which he believes to be from the lunar volcanoes.

Analyses.

No. 1. Meteorite from Tazewell County, Tennessee.

		Corresponding to	
Iron	83·02	Nickeliferous iron	98·97
Nickel	14·62	Schreibersite	1·03
Cobalt	·5		
Copper	·06		
Phosphorus	·19		
Chlorine	·02		
Sulphur	·08		
Silica	·84		
Magnesia	·24		
	99·57		100·00

In which Nickeliferous iron contains—

Iron	82·59
Nickel	17·41
	100·00

Schreibersite—

Phosphorus	15·47
Nickel	29·17
Iron	55·36
	100·00

No. 2. Meteorite from Campbell County, Tennessee.

Iron	97·54
Nickel	0·25
Cobalt	·06
Copper	(a trace)
Carbon	1·5
Phosphorus	·12
Silica	1·05
	100·52

No. 3. Meteorite from Coahuila, Mexico.

		Corresponding to	
Iron	95·82	Nickeliferous iron	98·45
Cobalt	·35	Schreibersite	1·55
Nickel	3·18		
Copper	(a trace)		
Phosphorus	·24		
	99·59		100·00

No. 4. Meteorite from Tucson, Mexico.

Iron	85·54	Nickeliferous iron	93·81
Nickel	8·55	Chromic iron	·41
Cobalt	·61	Schreibersite	·84
Copper	·03	Olivine	5·06
Phosphorus	·12		
Chromic oxide	·21		
Magnesia	2·04		
Silica	3·02		
Alumina	(a trace)		
	100·12		100·12

No. 5. From Chihuahua, Mexico. Not analysed.

The other details as to the structure, form, physical characters, &c., of these meteorites are not susceptible of abridgement. But they all present evident marks of fusion or igneous action; while the author's inference as to the *fragmentary* nature seems somewhat doubtful.

"Experiments on Light, referring to the *apparent magnitudes* of Luminous Meteors."

(Prof. L. Smith's Memoir, p. 30.)

In the author's experiments three solid bodies in a state of vigorous incandescence were used: 1st, charcoal points transmitting electricity; 2nd, lime heated by the oxy-hydrogen blowpipe; 3rd, steel in a state of incandescence in a stream of oxygen gas. They were observed on a clear night at different distances; and the body of light (without the bordering rays) compared with the disk of the moon, then nearly full, at 45° above the horizon. The results are given in the following table:—

	Actual diameter.	Apparent diameter at 100 yards.	Apparent diameter at ¼ mile.	Apparent diameter at ½ mile.
Carbon points	·3 inch	½ diam. of ☽	3 times ☽	3½ times ☽
Lime light	·4 inch	⅓ diam. of ☽	2 do.	2 do.
Incandescent steel globule	·2 inch	¼ diam. of ☽	1 do.	1 do.

If then, the author argues, the apparent diameter of a luminous meteor at a given distance is to be accepted as a guide for calculating the real size of these bodies, they would be (according to the table given by Prof. Olmsted (Am. Journ. of Science, vol. xxvi. p. 155) for estimating the diameters of meteors in comparison with the moon),

Charcoal points	80 feet diameter.
Lime light	50 " "
Incandescent steel globule	25 " "

A large meteor observed at Wilton was estimated by Mr. E. C. Herrick (Am. Journ. of Science, vol. xxxvii. p. 130) to be about 150 feet in diameter. It appeared to increase gradually in size until just before the explosion, when it was at its largest apparent magnitude of $\frac{1}{4}$ the moon's disk: exploded at 25° or 30° altitude with a heavy report, which was heard 30 seconds after the explosion was seen. One or more of the observers saw fragments descend to the ground. When it exploded it was three or four miles from the surface of the earth; immediately after the explosion it was no longer visible. The large size of the body is inferred from the fact of its appearing $\frac{1}{4}$ of the moon's diameter about six miles' distance.

After the experiments above recorded, the uncertainty of such a conclusion is evident. A body in a state of incandescence might exhibit the apparent diameter of the Wilton meteor at six miles' distance and not be more than *a few inches* or *a foot* in *actual* size, according to the intensity of the incandescence.

It ought to be added that Mr. Herrick (in the paper referred to) expressly allows for some uncertainty of this kind.

The author further instances another large meteor observed at Weston, and estimated by the same kind of calculation at *a mile and a half in diameter*: on the principle of these experiments it need not have been more than *one or two feet.*

No. 6.—Extract of a Notice of a Shooting Star, by Prof. C. Piazzi Smyth. From the Proceedings of the Royal Society of Edinburgh, No. 34, Feb. 5, 1849.

This instance, the rare one of an *ascending* shooting star, was furnished by Captain W. S. Jacob, Bombay Engineers; and he having given the place where the body first appeared, that where it disappeared, and the time, with great exactness, it was considered by the author to afford a good case for testing the theory of Sir J. Lubbock.

Allowing that many phænomena of an atmospheric kind may have been confounded with true shooting stars, still, the author observes, a great proportion are undoubtedly of a cosmical nature, and belong properly to astronomy; and these may be divided into two classes of small bodies. 1st, Those which are circulating round the sun as a primary; and, 2ndly, Those which are revolving round the earth as such. The first we may occasionally see when passing near them in their orbits, but are not likely to come within sight of the same again, unless, indeed, they approach so near the earth as to gravitate towards it instead of the sun, and so become satellites or shooting stars of the second class.

Sir J. Lubbock's theory is, that the shooting stars shine by reflected light, and are extinguished by entering the earth's shadow; and he has given formulæ on this supposition for computing the distance of the body from the spectator by noting the place in the sky where, and the time when, the extinction occurs.

These formulæ have been rendered more convenient for computation by Mr. Archibald Smith, Phil. Mag., March 1849; and, computed according to them, Captain Jacob's observation gives, for the distance of the body from the observer, 1721 miles: and that entry into the earth's shadow was the true cause of the disappearance, is borne out by the fact that the direction of motion was *towards* the axis of the earth's shadow. And, on account of the extremely small distance of the body, its change of place during flight would sufficiently account for its gradually appearing in the lower part of the sky when coming out of conjunction, increasing in brilliancy during its

flight (reaching, at its maximum, the brightness of Venus), and then slowly vanishing as it entered first the penumbra and then the umbra of the earth's shadow, in a slanting direction; and lastly, the body can hardly fail of being a satellite, as its distance is so much less than that of a shooting star, which M. Petit of Toulouse has pretty well identified as revolving about the earth in 3^h 20^m, or at about 3000 miles from the surface.

No. 7.—Letter from Dr. Forster, *Times*, August 17, 1857.

"Extraordinary Coloured Meteors.

"*To the Editor of the Times.*

"Sir,—I venture once more to trespass on your valuable time and paper to communicate the following extraordinary phænomena to the public, since, if similar meteors should have been seen in different latitudes, such registers may tend to useful results, as well as to solve the long-disputed question of the cause of meteors. Monday, being the 10th of August, astronomers were all on the look-out for the periodical falling stars. I began my watch on the 9th, when some few brilliant examples occurred. On the 10th they were more numerous, as also on the 11th; but on the 12th, that is, last night, they assumed very unusual forms and colours. Being at Ostend I returned late to a good position above the sea, and watched them great part of the night. Many hundreds fell in various directions, but particularly towards S.W. and W., not N.W. as usual. They did not in general move fast and leave the white trains behind them, as is usual, but descended slowly with a bright yellow flame; others were splendidly crimson, and some bright blue and purple. This fact is very curious, as favouring the hypothesis of ignited gases, adopted by M. De Luc of Geneva; and it would be interesting to ascertain whether this coloration of the meteors has been observed in other places far from the influence of the sea. I have ascertained that during the whole of this month meteors have been numerous all along the Rhine and in Germany. Such numbers have not fallen since the 10th of August, 1811, nor have we any record of such a quantity as on the present occasion, extending over four days consecutively, and exhibiting such very brilliant and diversified tints of light.

"Collaterally with these meteors the following phænomena should be noticed, proving the highly electric state of the air. In the storm which raged in Holland on the 5th of July, the hailstones were larger than pigeons' eggs, and broke nearly all the windows in Arnheim. The same occurred at Spa on the 5th of August, when every pane of glass exposed to the hail was beaten to pieces. All the electrical instruments indicate a high positive charge. A *trombe* or waterspout was witnessed by me in the distance on the 11th. The showers have not cooled the air, as they usually do. A new weathercock with several horizontal and vertical fans and wheels, which I have put up in order to test the wind, shows that the varying gales have not blown horizontally, but slanting, or in undulations, and the thermometer has risen again to Indian heat. All these circumstances point to some cause of the changes of temperature not at all depending on the place of the sun, and which future observations may more fully develope, if astronomers will accurately observe them in various parts of the world. We may possibly derive therefrom what has long been a desideratum in science—a table of true indications of the changes of weather.

"I submit all or any of these observations to your better judgment for insertion, and have the honour to remain,

"Your obedient servant,

"Brussels, Aug. 13." "T. Forster."

On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains. *By* C. Vignoles, *C.E., F.R.S.*

The following observations are submitted to the British Association as appearing to possess sufficient interest for discussion, from the circumstance of differences of opinion amongst civil engineers having thrown doubt upon the feasibility of applying the principle of suspension to the purpose of railway transit.

But the practical success in America of this principle on a large scale may be quoted as an example in its favour, and is a striking set-off against the failure in this country, which occurred upwards of five-and-twenty years ago, under circumstances which have militated against any attempt to repeat the experiment. Some debate on this question took place in the Institution of Civil Engineers of London, at a meeting last spring, from which many engineers were absent; and as the subject was on the intended application of a suspension bridge to carry a railway across a navigable river in the North of Ireland, a further inquiry may not be wholly uninteresting at a meeting held in the Irish capital, where many engineers and other practical and scientific men may be present, and who, not having had a previous opportunity of joining in the inquiry, may be disposed to propound their opinions.

A further reason for bringing the subject forward, and one which will naturally create a more extended interest in the discussion, is, that the recent events in India cannot fail to produce, among the remedial measures to be applied, a general and a more rapid extension of railways, even to the most remote parts of our Asiatic dominions, and in the course of this extension many rivers of great breadth must be bridged.

It is desirable to condense the matter into a few salient and important points, and it may be generally assumed that the whole inquiry is comprised under the following heads, viz.—

1st. The maximum load to pass the bridge.

2nd. The velocity of the train. And these being given, there are then to be determined—

3rd. The strength of the chains.

4th. The rigidity of the platform; which having been duly provided for, the additional considerations will be as to—

5th. Prevention of undulation, vibration, and oscillation.

1st. *Maximum load to pass the Bridge.*—This load may be taken as equal to the weight of the locomotive engine and tender, and of as many carriages as will extend on a single line of railway along the platform of one whole opening between the suspension piers; to the consideration of such a single line the inquiry may be confined.

The length of the train, and consequently the weight on the platform of the bridge, will therefore be in proportion to the span or opening. The weight of an engine and tender may be taken, speaking roundly, at one ton per lineal foot of the railway over which they pass, and the weight of loaded carriages at half a ton per lineal foot. For a bridge with a clear opening of 400 feet, the weight of a train extending the whole length of the platform would average little more than half a ton per lineal foot; but as it has been generally customary to compute the insistent load on railway bridges at one ton per lineal foot of single line, this weight will be the one assumed.

2nd. *Velocity of the Train.*—It would be opening too wide a field upon the present occasion to inquire into or to attempt to solve the complex problem of what additional gravitating effect is produced upon railway

structures by the percussive action of trains moving at different velocities. It must be admitted, *in limine*, that we have not at present sufficient justification to recommend that railway trains should be allowed to pass over the platforms of suspension bridges except at moderate speed; nor, as a matter of every-day practice, should the locomotive engine be allowed to act, except slowly, while passing over such a bridge.

With these limitations of speed, and of action of the driving-wheels, of the locomotive, the resistance to weight which must be provided for in a railway suspension bridge, need not be more than to meet the maximum load above assumed, namely, one ton per lineal foot of the platform, in addition to the weight of the platform itself, of the chains and their accessories, and of the suspension-rods, all of which are matters of strict calculation dependent upon the span.

3rd. *Strength of the Chains.*—The mathematical theory of suspension bridges has been so fully entered into by the best foreign and English authors, more particularly by the French, amongst whom M. Navier is the most distinguished, that little need be said now, except to give the best admitted *formulæ* for calculation. There is so little practical difference in the form of the curve which the chain of a suspension bridge assumes when freely suspended without a load, and when fully loaded, that is, the difference in form between a catenary and a parabola, that the most esteemed writers on this subject have, by common consent, agreed to consider the curve of the chain of such a bridge to be a parabola rather then a catenary, on account of the very much greater simplicity of the mathematical calculations. Perhaps it may not be irrelevant to enter very briefly into this.

When a heavy chain, freely suspended from two fixed points, is acted on by the force of gravity only, the form of curve which it assumes is called *the catenary.* If, however, the chain be loaded with weights, distributed in such a manner that for each unit of length (*ex. gr.* for each foot), measured along the horizontal tangent at the lowest point of the curve, the weights should be equal to each other, the effect of such a distribution is to cause the curve of the chain to approach in form to another curve called *the parabola.* If the distributed weights become so great that the weight of the chain may be neglected in comparison with them, the form which the curve assumes in this case is accurately that of the parabola.

In most, if not all ordinary cases, the weight of the chain is, however, never inconsiderable in relation to that of the platform and of the testing-load together; and consequently the form of the chain is never exactly that of the parabola, though it approaches more nearly to this curve than to the catenary; so near, that for all practical purposes it may be considered to have attained that form, viz. of the parabola.

In the case where the curve of the principal openings has a chord, say for instance of 424 feet, and a versed sine of $29\frac{1}{4}$ feet, or the proportion between the chord and versed sine of between 14 and 15 to 1, the two curves (catenary and parabola) passing through the points determined by these conditions approach so near to each other in form, that their greatest distance, measured in a vertical line intersecting both of them, is only 0·6 (3)5th) of an inch.

4th. *The Rigidity of the Platform.*—This is perhaps the most important point of the subject, and has probably hitherto been least considered, and, strictly speaking, the novelty of the inquiry is confined to this alone. In all the earlier examples of suspension bridges, the object of the engineer appears to have been to construct the platform as light as possible. In many instances this was carried to a most dangerous extent; even in the

case of the great suspension bridge over the Menai Straits, the platform has been repeatedly damaged by storms of wind, which twisted it as if made of pasteboard. The late Mr. Rendel was the first engineer who perceived the mistake which had been hitherto committed in this respect. When the suspension bridge at Montrose had been destroyed about twelve or fourteen years ago, he reconstructed the platform and stiffened it by bracings so effectually that it has since remained uninjured. This principle of strengthening the suspended platform was carried out to a greater extent by the writer of these observations at the bridge over the Dnieper at Kieff, in Russia, and the successful resistance of this well-braced platform to the effect of hurricane winds, and to vibration, oscillation, and undulation, has been very remarkable.

The desideratum is, that the platform of a suspension bridge intended to sustain a railway train should be made as stiff as possible; and the first natural consideration is, how is this stiffness or rigidity to be best obtained? The mode in which this has been effected in the great Niagara suspension bridge, is on the system of a deep trellis frame,—in fact, a timber tube, the sides of which are of lattice-work, the railway passing on the top.

It is generally understood, and a print published at the time seems to confirm this, that the original intention of Mr. Stephenson was to have added suspension chains for supporting the tubular platform of the Britannia Bridge, although that intention was subsequently abandoned, and the tubes made sufficiently stiff not to require their assistance.

Another great point in this discussion seems to relate to the adapting of suspension bridges for passing railway trains in localities and under circumstances where fixed bridges could not be erected except at an unjustifiable expense, or not at all, from the onerous conditions naturally or judicially imposed.

According to the locality, timber or iron may be best suited for constructing the platform, the platform being made as deep and as stiff as possible, and thus becoming a girder held up by suspension chains; and the stiffness being augmented by the increased depth of framing, it will be advisable that the rails should be attached thereto as high up as practicable. But the weight of the platform must be kept within reasonable limits, to avoid too great an increase in the sectional area and weight of the chains, which would otherwise become necessary; and further precautions have to be taken as regards the distribution of the load on the platform, and to guard against oscillation and undulation, for all which due consideration must be given as to the proper breadth of the platform.

The weight of the platform of an ordinary suspension bridge was formerly scarcely more than 36 lbs. to the square foot of the area of the whole platform; the present weight of the Menai Bridge platform, after having been strengthened, is about $38\frac{1}{2}$ lbs. to the square foot; the weight of the platform of the Montrose Bridge, as reconstructed by Mr. Rendel, is $41\frac{1}{2}$ lbs. to the square foot; and the weight of the platform of the Kieff Bridge is $49\frac{1}{2}$ lbs. to the square foot, including the two footpaths which are corbelled out from the main part of the framing; but the weight of that part of the platform between the chains, and which sustains the roadway, is about 60 lbs. to the square foot. The ordinary test-load for a suspension bridge was about 62 lbs. to the square foot; the proof-load put upon the Kieff Bridge was really about 84 lbs. to the square foot.

Now a railway-load passing over a suspension bridge being taken at one ton per foot forward, the weight per square foot upon the platform will vary as the breadth of the bridge: if the bridge be 20 feet, the passing load

will be one cwt., or 112 lbs. to the square foot; if 27 feet wide, it will be 83 lbs.; and if 30 feet wide, 75 lbs. to the square foot. The Kieff Bridge is $52\frac{1}{2}$ feet wide, and therefore a passing load of one ton per lineal foot spread over this area, is only 43 lbs. per square foot, whereas the test-load was 84 lbs. to the square foot, which is about double what would have been the weight of the heaviest railway train; or taking 42 feet, exclusive of footpaths, the railway-load would have been 52 lbs. per square foot, or less than two-thirds of the test-load, which, it may be remarked, has remained on forty-eight hours without the platform showing any deflection visible to the eye, although some deflection really took place.

It appears therefore most undoubted, that suspension bridges of modern construction may be perfectly adapted to sustain the passage of railway trains, and that the chief consideration has to be given to the character and dimensions of the platform; and as a general rule I would suggest, that notwithstanding the advantage to be gained by depth, this should not be carried too far, more especially if the lattice-girder system be adopted, as it presents too much surface to the wind, and thus induces increased lateral oscillation. Also, that the breadth of the platform for a single line should not be less than 25 feet, in order to spread the load and reduce the insistent weight per square foot of platform.

It might be interesting to establish a comparison of the expense of various descriptions of platform, but this would lead too much into detail, and the materials for this purpose have yet to be collected. Still, as a contribution, and by way of illustration, the present opportunity may be taken to state the cost of the platform of the Kieff Bridge, already mentioned as so remarkably stiff, and capable of sustaining the transit of a railway train.

In a length of 12 feet of the whole breadth of $52\frac{1}{2}$ feet of the platform, the quantity of materials was as follows:—

Timber, 600 cubic feet	£150	0	0
Iron, 30 cwt.	30	0	0
Total....	£180	0	0

for a length of 12 feet, or £15 per lineal foot of the whole breadth of the platform, which is something less than six shillings per square foot of a platform such as that at Kieff (of which the drawings were shown).

5th. *Prevention of Undulation, &c.*—The effects upon a suspension bridge of passing loads and of strong winds, cause vibration, oscillation, and undulation. Of these, the undulation is considered to be the most serious. The vibration may be assumed as produced by what may be called the percussive action of the passing load, and when the platform is not sufficiently stiff, and the passing action is irregular over the surface, as, for instance, by the impetuous rush of a drove of cattle, or of a multitude of people, oscillation and undulation ensue; the first producing a lateral swing of the platform, the latter arising from the bending of the platform in its longitudinal direction.

The remedy for vibration and oscillation is provided by a sufficiency of stiffness, not to say absolute rigidity, in the platform, which will also, to a certain extent, counteract the propagation of the undulation, but not entirely.

The experience, however, of four years on the Kieff Bridge, has proved that the mode adopted in that construction of disposing the suspension rods *alternately* (in the manner shown on the exhibited drawings) has completely counteracted the undulation; and many very heavily-laden carriages together, —artillery, cavalry, and large bodies of troops,—have been continually

passed over the platform of this bridge without the slightest undulatory or oscillating motion having been produced.

We are hence enabled to infer, without looking to improvements in detail, which will naturally be introduced, that a platform so constructed and so suspended as the one at Kieff, is capable of sustaining the passage of railway trains at a moderate velocity, and within a reasonable cost of construction; and taking the example of the wire bridge in America, and of this wrought-iron chain bridge in Russia, it may be legitimately concluded, that the adapting of suspension bridges to railway purposes is perfectly practicable.

The extent to which this application may be made can scarcely be defined *à priori*, but the writer ventures, from his own experience, to state his opinion, that where the span of the required bridge must exceed 300 feet, the suspension principle should be adopted for the sake of economy.

It would be extending these observations far beyond the bounds assigned to such meetings as these, to go further into the details, and therefore, however tempting the opportunity, we must abstain from entering upon the subject of the modern mode of obtaining foundations and forming river-piers, which mode would greatly influence any selection between a fixed or a suspension bridge. Neither must we even touch upon the choice between the wire-rope and the wrought-iron plate chain, as the means of suspending the platform, though it is obvious that where the span becomes very large, the superior lightness of the wire is a great inducement to decide the preference for it over the wrought iron.

The proportion between the chord and the versed sine of the curve of the suspending chain is another point of the highest interest, as relating to the questions of more or less oscillation, and of increase or decrease in the amount of tension, as this proportion varies.

It is sufficient to have brought the general subject of the practicability of adapting suspension bridges to sustain the passage of railway trains before the Mechanical Section of the British Association; and it is to be hoped that this opportunity will not pass away without engineers and the other scientific and practical men now assembled, bringing their judgement and experience to an examination of this very important question.

On Electro-Chemistry. *By* Professor W. A. Miller, *M.D., F.R.S.*

In reporting upon the recent progress of electro-chemical research, the author stated that the inquiries made of late years in the field of electro-chemistry were characterized rather by modifications of the laws previously admitted, than by any fundamental additions to the existing stock of knowledge upon the subject.

Faraday's observations on the exceptional conducting power of solid sulphide of silver, and one or two other substances when heated, had been traced, by the researches of Beetz and Hittorf, to true electrolytic decomposition, which is rendered possible by the somewhat viscous condition produced by heating these bodies. The true electrolytic nature of the decomposition was proved, first by the rise in conducting power, occasioned by rise of temperature (whereas in metals the effect is exactly the reverse); and secondly by the effects of polarization observed upon the electrodes between which such bodies are placed.

Allusion was then made to the experiments by Bunsen on the insulation

of metallic bodies by electricity; in the course of which he had shown that in many instances, as in the decomposition of a solution of sesquichloride of chromium, the deposit upon the negative electrode could be made to assume the metallic form by reducing the surface of this plate to dimensions considerably smaller than those of the positive electrode, a result probably owing in part to the secondary decomposition produced in the limited portion of liquid around the wire, whereby the sesquichloride was reduced to the protochloride of chromium and subsequently the metal itself was deposited. This view was rendered probable by observing the effects obtained during the electrolysis of sesquichloride of iron, in which these successive steps could be distinctly observed. In cases in which, like the chloride of manganese, the compound was already in the condition of protochloride, it was unimportant whether or not the negative electrode presented a smaller area than the positive electrode. Attention was called to the fact pointed out by Faraday of the non-existence of more than one electrolyte in a multiple series; thus in the case of the two chlorides of tin, the fused protochloride is an electrolyte, but the bichloride, although a liquid at ordinary temperatures, is not an electrolyte if anhydrous. Yet the bichloride when dissolved in water, itself also not an electrolyte, conducts freely; and a similar result is obtained in other analogous cases.

Referring to the decomposition of salts in solution, the bearings of electrolysis upon Davy's binary theory of the composition of salts were briefly alluded to, and some of the difficulties attending the adoption of this theory in the case of the subsalts were mentioned; these facts, taken in conjunction with those already alluded to in the case of the bichloride of tin, leading the author rather to the view that a salt is to be regarded as a whole, susceptible of decomposition in various modes (just as a crystal may admit of cleavage in two or three different directions according to the method in which the force is applied), and therefore admitting of representation under two or three different rational formulæ, each of which may, under particular circumstances, be advantageously employed.

Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ *N., long.* 156° 17′ *W., in* 1852–54. *By* JOHN SIMPSON, *Esq., R.N., F.R.C.S., F.R.G.S., Surgeon of H.M.S. 'Plover.'*

[With a Plate.]

AT p. 331 of the ninth volume of the 'Royal Geographical Society's Journal,' 1839, Sir J. Richardson, in reference to Sir David Brewster's discussions of an hourly register of the temperature at Leith Fort, says:—

"Convinced of the importance of investigating the phænomena of diurnal temperature in various latitudes, I have thought that a discussion of the thermometrical observations made on Sir E. Parry's several voyages would be a service rendered to science." Following the lead thus indicated, it has appeared to me that the results of the observations made at Point Barrow would be a valuable though small addition to those given by Sir J. Richardson, to whose form of tables I have adhered, only making additions, as the means of the *decades* or three divisions of each month, where I thought this could be done without marring the original purpose of the table.

The observations now offered were made with great accuracy, and possess the advantage of having been registered every hour at one spot from the 3rd of September 1852 to the 7th of August 1853, and for a few days before

and after these dates in the neighbourhood, making a complete year, less 21 days. Again, in precisely the same locality, from the 7th of September 1853 to the 19th of July 1854, to which have been added the six first days of September, and one day, the 20th of July, during which the ship was in the immediate neighbourhood, making a second complete year, less 42 days. The ship returned again to the same spot on the 27th of August 1854, and remained four whole days, for which the hourly register gave a mean temperature of 39°·448, serving as a fair guide in estimating the temperature of the last eleven days of August, which accordingly has been assumed to be 39°·448, thus reducing the interval in the last year to thirty-one days.

To fill up the interval of twenty-one days' absence in 1853, the mean temperature of these has been assumed at something between the decades last preceding and first following that period. Thus, the first ten days of August giving a mean of 38°·441, and the first ten of September giving a mean of 32°·146, the second and third decades of August have been assumed as 37° and 35° respectively. In the same manner, to fill up the interval of thirty-one days in the summer of 1854, the second decade of July giving a mean of 38°·287, the mean of the last eleven days is assumed to be 39°. The last eleven days of August having been calculated to give a mean of 39°·448, as already stated, the intervening two decades can, without much risk of error, be assumed at 40°.

The thermometers used throughout the period of observation were made by Adie and Co. of Edinburgh, in February 1848; and having been returned to the Hydrographer's Office, Admiralty, in April 1855, I have no doubt some of them could be obtained there, if required for comparison with any acknowledged standard. There were six of them, numbered from 10 to 15, and remarkably alike in appearance and size. To each was attached a graduated glass scale, on which, besides the number, was cut the maker's name. On application at Messrs. Adie's establishment, Edinburgh, I obtained the following information as to their mode of construction:—

"For spirit thermometers constructed February 1848,—

Before use, colourless alcohol,	sp. gr.	·79465.
Before use, coloured „	„	·79537.
After use, „ „	„	·79541.

"Points fixed from standard mercury thermometer 62° and 32°. Scale then run down to −56°."

They were on several occasions exposed together to different degrees of cold, and were very uniform in their indications down to the lowest temperatures registered. Subjoined is a table of thermometers compared (p. 161).

It appears from this Table that five of the instruments by Adie indicated a mean of 35°·5 nearly as the freezing-point of mercury, whilst that by Cox of Devonport stood at −41°, and that by Pastorelli at −48°.

Pastorelli, No. 419, had an error of −1°·5 at the freezing-point of water; and at our lowest temperature its indications were 13° below Adie's.

Cox's thermometer, No. 1, had an error of 2° at the freezing-point of water, but at lower temperatures corresponded much more nearly with Adie's. Like Pastorelli's, however, it had the disadvantage of a heavy box-wood scale, preventing it from indicating rapid changes of temperature, which the glass scales of Adie's instruments permitted. Both these were rejected for ordinary use.

The mercurial thermometer used as a standard was Pastorelli, No. 406. This also had a heavy box-wood scale, but I believe was otherwise a good instrument, and, if sufficiently long exposed to a uniform temperature, could be trusted as low as 32° below the zero of Fahrenheit. At that point the

Comparison of Thermometers at low Temperatures.

Maker's Name.	No.	Immersed in Snow and Water.	Exposed to the air, suspended.									
			15th Oct. 1852.	19th Oct. 1852.	17th Jan. 1853.	19th Jan. 1853.	1st Feb. 1853, a.m.	1st Feb. 1853, p.m.	Feb. 1854.	Mercury freezing and melting.		
Spirit Thermometers.		+°	+°	−°	−°	−°	−°	−°	−°	−°	−°	−°
Cox, Devonport. Colour of spirit deep red; boxwood scale......	1	30	12	18	32	44	27·5	25	35	41	46·5	49
Pastorelli & Co. Colour deep red; boxwood scale..........	419	30·5	11	23·5	38	53	34	31·5	41·5	48	56	59
Adie & Son, Edinburgh. Colour pale red; glass scale..........	10	32	13·5	15·5	32	42	25	22·5	31·2	36	43	46
Ditto ditto................	11	32·3	14·5	14	28*	40*	24	22	31·7	34*	43	45·5
Ditto ditto................	12	32	14·5	15	30	42	25	22·5	...	...	...	...
Ditto ditto................	13	32	14·5	15	...	...	25	22·5	31·2	35·2	43	46
Ditto ditto................	14	32	14·5	15	29	41	25	22·5	31·2	35·7	43	46
Ditto ditto................	15	32	14	15	28	40	25	22·5	30·5	35·5	42·5	45·5
Mercurial Thermometers.												
Pastorelli & Co. Boxwood scale	406	32·5	9	17	32	...	...	...	...	...	...	...
Simpson, Strand. Boxwood scale	...	32	13	17	32	...	...	...	...	...	...	...

* Adie & Co., No. 11, was the instrument in constant use, and on the 17th and 19th of February, 1853, was in its usual place attached to a post, whilst the others were suspended a little apart. On a subsequent occasion its bulb was immersed in the freezing and melting mercury, when its indication was −34°.

tube seemed to become irregular; and on solidifying, the mercury sank completely into the bulb.

A curious circumstance happened with this instrument on one occasion. Believing the quicksilver in it to be pure, I placed it beside one of Adie's, exposed to the air at a temperature about the freezing-point of mercury, for the purpose of ascertaining the exact degree indicated by Adie's at the moment of solidifying. Whilst attentively watching it, to my surprise the column of mercury suddenly shot up the stem to $-4°$, then slowly but steadily descended into the bulb. Though I heard no sound of the glass cracking, I thought the bulb had given way, and the entrance of air had forced the mercury up the tube; but in this I was mistaken, for having taken it on board and thawed it, nothing wrong could be detected, and it worked as well as before. The explanation which offered itself to my mind was, that the surface of the mercury in the bulb becoming at once solidified, its contracting pressed the central and still fluid portion of the metal into the stem with a jerk, and thence again gradually absorbed it as the process of freezing approached the centre.

Whether these instruments by Adie were absolutely correct seems doubtful. In my Journal I find the following remarks regarding them:—

"Feb. 2, 1854.—Temperature fell to $-39°$ in the night, when I had a good comparison of the thermometers, those of Adie's remaining within a degree of $-39°$, whilst a quantity of quicksilver in a teacup partially froze. The quicksilver remained out all night, and did not become completely fluid again until 9 a.m., when the temperature had been some hours at $-36°$, $-35°$, and $-34°$. A mercurial thermometer placed in it also stood at $-34°$, and the same one now blackened for exposure to the sun's rays and enclosed in a glass case has fallen to $-52°$, *i. e.* become solid, whilst the one (Adie, 11) in constant use shows only $-37°{\cdot}5$."

"Feb. 3, 1854.—One of the new thermometers was kept in the vessel in which the quicksilver was exposed; and it remained all day at $-36°$, whilst its fellows showed $-39°$ and $-40°$. On removing it a small portion of the solidified metal adhered to the bulb and still remains attached, although the temperature indicated by it and the others is $-37°$. The result of this is either that the mercury is impure, which I believe is not the case, or the instruments have an error of 3 or 4 degrees."

"Feb. 4.—The mercury adhering in the solid state to the bulb of the spirit thermometer remained in the same state until half-past two this morning, when it dropped off, that and the four other thermometers by Adie showing $-36°$."

From these experiments, I incline to the belief that an error of 3 or 4 degrees will be found to exist in these instruments at the freezing-point of mercury. The quantity of metal in the teacup was several ounces, and therefore too large, unless its indications be taken while partially solid either in freezing or melting. I have considered the dropping off of the small portion adhering to the bulb of the spirit thermometer as the best index.

The mercurial thermometer alluded to as descending to $-52°$, was one attached to a scale apparently graduated regardless of accuracy; but from some experiments made with it, I considered the tube was tolerably uniform in calibre; I therefore removed the scale, and attached another reaching down to within half an inch of its bulb. This scale was graduated by comparison with Pastorelli (mercurial), as low as $-32°$, and thence the graduation was continued to the bottom of the scale in the same proportion, bringing it down to $-50°$, about two degrees below which the mercury always stood when solid.

The spirit thermometer for use was placed in a tin cylinder $2\frac{1}{2}$ inches in

diameter, with a longitudinal opening through which it could be easily read; this cylinder was kept in another of the same material which was painted white, seven inches in diameter, having a conical projecting roof, and a flat bottom, with numerous small openings in both, and a door opening like a common tin lantern: this again, with its door facing the north, was fixed to a stout stake, placed in the ice at a distance of 90 feet to the eastward of the ship. The arrangement so made was to protect the instrument from the wind and snow-drift, and from the influence of the sun, while admitting the easy access of air. To have placed it further from the ship would have been to put it in the way of natives, who might steal or break it; and as the ship's hull was banked round with snow, and the prevailing winds came in from the N.E., it was thought the effect of her presence on the thermometer at that distance would be little or none.

The position of the ship at Point Barrow was at the extremity of a narrow point or spit of gravel, which at no part rose more than 6 feet above the ordinary sea-level, and about five miles distant from the mainland of the American continent. The coast trended on one side to the S.W., and on the other to the E.S.E., and was uniformly low and flat in the latter direction for 150 miles, whilst to the S.W. there was no elevation near the coast approaching 100 feet for a like distance. The mainland to the south had not been explored for more than twenty or thirty miles, to which extent it was perfectly flat, and the natives described it as quite level for several days' journey further, beyond which it became hilly, and far south mountainous. The climate, therefore, may be described as maritime or almost insular, and was not subject to such extremes of temperature as the land. This was ascertained by the register kept by Capt. Maguire on a journey to the hunting-grounds during the coldest part of the year, the temperatures recorded by him being generally lower than those taken at the ship during his absence. In the summer the shooting-parties recorded higher temperatures on the land than were observed at the ship.

The long polar night, or observed absence of the sun, was 69 days, from November to January; and the continued presence of the luminary in the summer, owing to refraction, embraced a period of 74 days.

The calculations for the following Tables were made at intervals of leisure, and, though simple enough, were very tedious and open to error; but this, I think, has been successfully avoided by the various cross checks I used. Each mean in the first twelve Tables is deduced from the sums of the observations, and in no instance from results already obtained. Some exceptions to this rule were made in producing the means of the two years combined.

Table I. gives the mean temperature of each day, and the mean of every 10 days (or, when the month consists of 31 days, the last division is the mean of 11, and the latter portion of February is the mean of only 8 days); at the foot of the table the mean of each month, and at the foot of the page the mean temperature of the whole year, as ascertained from 8760 observations, those of the last 21 days of August having been intercalated as already stated.

In this Table a remarkable rise of temperature will be observed before and after the winter solstice. The month of December set in cold the first 10 days, giving a mean of $22\frac{1}{2}$ degrees below zero, whilst the second decade presented a mean of only half a degree below that point; and the last 11 days rose to $6\frac{1}{3}$ above it. The mean of December is little more than one-tenth of a degree lower than that of October, and is nearly 4 degrees higher than November: this was owing to a southerly gale which almost produced a thaw for 3 days at the winter solstice, and had the effect of driving the ice completely off the coast, leaving nothing visible from the beach to the furthest

range of vision, east, north and west, but the open ocean and a water sky. This was succeeded by intense cold in January, when the sea speedily froze over again.

The periods at which the mean temperature of the year occurred in spring and autumn were at the middle of October and April, or rather more than 20 days after the equinoxes; but the period of greatest cold was a month after the winter solstice, and the greatest summer heat appears to have occurred in the beginning of August, or 40 days after midsummer.

TABLE II. gives the highest and lowest single temperatures of each month, the means of the highest and lowest daily temperatures for each month, and the means of these or of the daily extremes.

This Table shows that the greatest monthly range of temperature occurred in April, and was no less than 73 degrees, only 22 short of the range for the whole year, which was 95; running from $+52°$ in summer to $-43°$ in winter. The mean of these two single temperatures was 3 degrees below the true mean of the year, whilst the mean of the daily maxima and minima accorded with the true means to nearly within half a degree.

TABLE III. shows the mean temperature of every hour for each month. By this, the hottest and coldest periods of the day may be seen, as well as the mean daily range for the month. The coldest and hottest times of the day were usually a little after 2 o'clock a.m., and a little before 2 o'clock p.m.; but the time at which the mean temperature of the month occurred was rather before 7 a.m. and p.m. In this the daily changes of temperature corresponded with the annual, in the intervals between the periods of the extremes and the means *following being shorter* than the intervals between the periods of the extremes and the means *preceding* them. The greatest range between the day and night temperatures took place in April, and was 11 degrees.

TABLE IV. shows the mean temperature of every pair of opposite hours. From this Table it does not appear at first sight that any pair of similar hours can be selected as corresponding to the monthly mean; but on closer examination, the pairs of 3 and 9 generally give a mean nearer that of the month than any others. This appears more distinctly in the succeeding tables, where the whole year is given.

TABLE V. gives the hourly mean for the seasons, for the summer and winter *halves* of the year, and for the whole 344 days, at the same locality. From the omission of the 21 days in August, the summer temperatures appear somewhat below the truth, and the same remark applies to the summer half and to the whole year. But this does not materially affect the main object of the Table, which is to exhibit the progressive change of temperature from hour to hour.

TABLE VI. shows the mean temperature of every pair of similar hours for the seasons, half-years, and year, as in the last Table. In the last column it will be seen that the pairs of hours giving a mean nearest the mean of the year are 3 and 9, or a little after; or at very nearly equal periods before and after noon and midnight, and not intermediate between the periods of the extremes and evening and morning means.

These first six Tables refer to the year 1852–53, beginning with September and ending with August; and the six following are corresponding ones for the year 1853–54.

TABLE VII. differs from No. I. in the periods before referred to being generally later, in the extremes being more marked, and in the mean temperature of the whole year being lower than that of the preceding one. Thus the periods of the mean temperature in the autumn and spring were nearer

the end of October and April, or about 24 to 30 days after the equinoxes; the extreme of cold was experienced in the first part of February, and the extreme of summer heat was probably about the end of the first decade of August.

The usual interruption to the winter cold was less decided, and took place at the beginning of the second decade of January, raising the mean of that month above December, as December in the preceding season had been raised above November.

TABLE VIII. corresponds to Table II. By it the range between the highest and lowest single temperatures will be seen to be 1 degree more than the previous year, and give a mean 3 degrees below the true one of the year, whilst the means of the daily extremes accord very nearly with it. The greatest monthly range took place in March, and was 65 degrees: 11 less than that of April of the preceding year, and 31 less than the annual range.

TABLE IX. is similar to Table III., from which it presents no very remarkable difference. In it April again shows the most marked range between the day and night extremes, amounting to more than $12\frac{1}{2}$ degrees.

TABLES X., XI. and XII. agree in their general features with Nos. IV., V. and VI., and are defective in the July and August columns from the absence of the ship.

The succeeding Tables are compiled to give the means of two years, for which purpose the observations for the omitted summer intervals have been intercalated.

TABLE XIII. gives the means of the decades or third parts of each month, and of the whole month. Also, the highest and lowest single temperature noted during the two years, the extreme thermometric range being 97 degrees. The mean of these two extremes was $+3^{\circ}{\cdot}5$, and the true mean of the two years was $+6^{\circ}{\cdot}882$, or 25 degrees below the freezing-point of water. The autumnal and vernal periods at which these temperatures occur, by this Table, are about 14 and 23 days after their respective equinoxes; but the extremes of heat and cold, which occur on the 8th of August (probably) and on the 8th of February, are more than double that number, or about 48 days, after the solstice. Here the interval between the summer extreme and the occurrence of the annual mean in autumn is 67 days, and from the latter to the time of the winter extreme is 117 days; from the winter extreme to the vernal period at which the annual mean occurs is 74 days, and from this to the summer extreme 107 days.

TABLE XIV. gives the mean temperature for two years, of every hour for each month.

TABLE XV. gives the mean of every pair of similar hours of Table XIV.

TABLE XVI. gives the mean temperature for two years of every hour for each of the four seasons, for the half-years, and for the year. In this Table it will be observed that the interval of time between the extremes and that at which the annual mean *following* takes place is perceptibly shorter than between either extreme and the time of the mean preceding it.

TABLE XVII. gives the mean of every pair of similar hours in Table XVI.

TABLE XVIII. gives the mean temperature of every hour for the month of June, for 22 days in July, and for the 21 days both before and after the 21st of June, from hourly observations taken with a blackened thermometer exposed to the sun's rays. This Table, though so limited, may be of some interest in regard to the growth of vegetation during the short summer of the Arctic regions.

TABLE XIX. gives the means of the pairs of similar hours in the first and third columns of Table XVIII.

Table I.—Containing the Daily, Ten-daily, and Monthly Mean Temperatures for One Year, from hourly observations made on board H. M. S. 'Plover,' at Point Barrow. Lat. 71° 21′ N.; Long. 156° 17′ W.

Day.	1852.				1853.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
1	+32·75	+16·12	+ 1·66	−21·42	−16·25	−24·54	−25·75	−20·29	+18·25	+31·62	+32·83	+43·08
2	33·60	14·29	− 6·16	30·87	28·00	9·83	25·62	31·62	9·54	28·00	36·45	37·70
3	40·21	10·45	9·21	15·38	23·92	0·87	15·79	24·96	9·79	29·25	33·62	35·91
4	34·00	11·41	7·12	14·33	16·37	6·29	8·95	11·50	7·54	27·50	32·29	36·16
5	38·17	6·20	4·08	15·17	30·08	3·41	15·16	16·25	5·41	29·41	32·95	34·33
6	38·29	4·25	0·62	22·29	28·83	14·83	13·12	15·37	8·16	30·12	32·08	38·79
7	34·12	5·54	+ 3·83	27·55	28·08	17·20	1·58	4·79	10·45	33·58	32·16	38·58
8	33·41	7·87	12·16	35·00	15·50	19·83	+ 8·79	+ 9·87	25·45	34·54	30·75	38·66
9	32·41	10·91	− 1·79	25·33	17·54	20·20	6·04	4·12	25·50	29·83	30·87	37·20
10	30·46	7·79	7·04	18·37	16·71	20·58	12·08	− 4·42	19·12	27·83	31·83	43·95
Means ...	+34·742	+ 9·487	+ 1·837	−22·571	−22·127	−13·762	−10·342	−11·521	+13·925	+30·170	+32·587	+38·441
11	31·46	11·87	+ 1·79	+ 1·33	17·29	28·62	19·04	+ 3·79	14·00	28·75	32·70	....
12	28·91	17·41	4·29	− 1·33	14·92	31·71	18·46	1·54	17·33	29·00	33·50	....
13	26·58	13·52	−14·41	18·04	13·75	26·87	22·37	− 5·66	25·85	27·37	34·00	....
14	22·08	5·12	22·00	15·04	24·08	24·50	24·96	+ 6·08	19·25	29·16	32·45	....
15	32·79	5·96	15·33	17·92	32·54	25·41	26·71	9·91	15·04	31·58	35·25	....
16	28·87	8·20	19·79	+ 0·42	36·62	14·20	22·12	21·00	26·87	31·87	34·87	....
17	30·41	8·91	29·75	20·25	36·89	17·33	29·89	20·16	19·75	32·75	36·50	....
18	28·66	−10·12	30·00	5·68	31·58	20·46	18·79	17·00	20·54	33·41	34·16	....
19	34·00	15·83	27·79	− 2·00	38·46	20·75	12·16	10·87	18·91	36·75	37·91	....
20	32·91	16·45	6·62	+20·71	38·58	19·25	17·62	6·08	17·08	35·29	38·70	....
Means ...	+30·687	+ 2·860	−15·962	− 0·594	−28·471	−22·912	−21·212	+ 9·079	+19·462	+31·595	+35·008	+37·000

21	32·39	−13·75	+ 3·33	+24·08	35·58	13·71	16·66	3·83	13·79	35·00	39·20	....
22	23·83	1·16	5·21	24·96	33·58	11·83	+16·20	5·45	17·00	36·16	36·66	....
23	19·75	+ 5·33	− 2·96	22·29	18·87	13·54	8·91	7·37	21·45	32·62	35·62	....
24	21·06	12·75	10·71	14·96	16·50	12·92	7·62	18·33	29·29	35·79	35·04	....
25	21·50	20·46	10·17	− 2·62	31·21	14·04	− 6·00	19·25	28·58	34·29	36·16	....
26	21·92	9·58	14·54	12·42	35·33	19·12	6·83	16·95	30·41	33·33	35·87	....
27	21·17	− 0·75	12·71	+10·96	35·08	19·25	12·58	23·79	24·58	32·75	40·00	....
28	18·33	+ 4·20	11·17	+ 9·08	29·50	15·29	13·87	22·16	23·79	33·37	34·16	....
29	15·37	0·29	17·33	−14·83	+ 1·33	....	17·12	25·33	23·95	33·83	36·37	....
30	14·96	2·70	27·66	+ 1·46	8·91	....	2·00	21·75	24·75	33·41	41·91	....
31	....	1·45	....	−14·92	− 5·17	....	2·08	....	26·95	....	45·45	....
Mean	+21·027	+ 3·729	− 9·871	+ 6·300	−21·039	−11·971	− 6·295	+16·425	+24·053	+34·058	+37·872	+36·00
Monthly Mean ...	+28·813	+ 5·307	− 9·223	− 5·441	−23·787	−17·373	−12·392	+ 4·661	+19·305	+31·941	+35·240	+37·00

By intercalating the temperature of the last 21 days of August at the rate given for the two decades, the mean temperature of the year would be:—Sum of observations +85331, −16812, ÷8760, = +7°·821 Fahr.

TABLE II.—Containing the Highest and Lowest Temperatures for each Month, the Means of the Daily Maxima and Minima for each Month, and the Means of these, or of the Extreme Daily Temperatures, from the 'Plover's' Register, Point Barrow, 1852–53.

Months.	Highest temperature in the month.	Lowest temperature in the month.	Means of maxima.	Means of minima.	Means of the extremes.
1852. September..	+42	+12	+31·56	+26·23	+28·90
October ..	+27	−21	+ 9·50	− 1·70	+ 3·90
November..	+25	−37	+ 0·50	−16·10	− 7·80
December..	+28	−37	+ 1·20	−18·60	− 8·70
1853. January ..	+16	−43	−17·60	−30·10	−23·85
February ..	+ 3	−36	−13·30	−21·60	−17·45
March	+24	−37	− 4·80	−20·70	−12·75
April	+33	−40	+11·80	− 4·10	+ 3·85
May	+44	− 6	+25·08	+11·30	+18·55
June......	+45	+17	+37·00	+27·20	+32·10
July	+52	+26	+39·23	+31·70	+35·45
August....	+49	+31	+43·20	+34·20	+38·70
Means	+32·33	−14·25	+12·84	+ 1·47	+ 7·159

The highest single temperature occurred 31st July, and was +52°.

The lowest single temperature occurred 19th Jan., and was −43°.

The extreme range for the year therefore was 95°.

And the mean of these extremes was +4°·5

Table III.—Showing the Mean Temperature of every Hour for each Month, from hourly observations made on board the 'Plover' at Point Barrow. Lat. 71° 21′ N.; Long. 156° 17′ W.

Hour.	1852.				1853.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
A.M. 1	+28·48	+ 4·58	− 9·06	− 6·06	−23·64	−18·11	−15·22	− 0·56	+13·93	+28·26	+32·84	+36·20
2	28·45	4·83	8·83	6·16	23·48	18·46	15·58	0·96	13·80	28·16	33·00	36·30
3	28·40	4·51	8·63	6·55	23·22	18·71	16·00	0·96	14·00	28·40	33·03	36·20
4	28·45	4·19	8·40	6·45	23·29	18·75	16·09	0·93	14·51	28·60	33·22	36·00
5	28·70	4·35	8·60	5·77	23·29	18·50	16·32	0·63	15·50	29·76	33·58	36·30
6	28·91	4·58	8·90	5·55	23·26	18·11	15·61	+ 0·76	17·77	30·60	34·09	36·70
7	28·91	4·70	8·96	5·58	23·35	17·71	14·71	2·13	19·19	31·56	34·58	37·30
8	28·90	5·00	9·16	5·64	23·45	17·32	13·38	4·26	20·32	32·43	35·45	37·80
9	28·85	5·48	8·90	5·58	23·84	16·78	11·55	6·10	21·84	33·24	35·80	38·80
10	29·07	6·16	8·86	5·29	23·93	16·53	9·77	7·76	22·77	34·16	36·51	38·90
11	29·25	6·80	8·73	5·35	23·64	16·17	8·67	9·60	23·55	35·16	36·84	39·70
Noon. 12	29·42	7·29	9·03	5·45	23·51	16·07	7·77	9·96	24·16	35·26	36·84	40·90
P.M. 1	29·18	7·03	8·90	5·13	23·74	15·82	7·32	10·33	24·19	35·86	37·25	40·80
2	29·13	6·70	9·06	5·09	23·93	15·96	6·83	10·26	24·06	36·10	37·48	41·10
3	29·10	6·29	8·93	5·03	24·13	16·00	7·19	9·83	24·12	35·23	37·55	41·30
4	29·27	5·93	9·83	4·77	24·16	16·32	8·45	9·50	22·97	34·76	37·22	41·10
5	28·97	5·96	9·90	4·87	24·19	17·21	9·93	9·40	22·42	33·90	36·67	40·20
6	28·87	5·90	9·83	5·16	23·87	17·71	11·54	8·13	21·64	33·06	36·42	40·40
7	28·0	5·54	9·90	5·06	24·19	17·92	12·93	5·80	20·25	32·30	35·93	39·10
8	28·70	5·25	9·56	4·87	24·35	17·82	13·74	4·16	18·98	31·33	35·29	38·40
9	28·55	4·24	9·46	5·13	24·09	17·58	14·06	2·93	17·54	30·70	34·80	37·90
10	28·50	4·12	10·00	4·97	24·06	17·53	14·64	2·40	16·03	29·76	34·22	37·40
11	28·52	4·03	9·93	5·22	24·00	17·89	15·00	1·50	14·93	29·13	33·79	37·00
12	28·25	3·87	9·93	5·77	24·22	17·93	15·22	1·06	14·48	28·76	33·38	36·80
Means ..	+28·813	+ 5·309	− 9·223	− 5·441	−23·787	−17·373	−12·392	+ 4·661	+19·306	+31·941	+35·240	+38·441

TABLE IV.—Showing the Mean Temperature of every Pair of similar Hours for each Month, and for comparison the Mean of each Month; from the 'Plover's' Register, at Point Barrow.

Hours.	1852.				1853.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
A.M. P.M. 1 and 1	+28·83	+ 5·80	− 8·98	− 5·59	−23·69	−16·96	−11·27	+ 4·88	+19·06	+32·06	+35·05	+38·50
2 and 2	28·79	5·77	8·95	5·63	23·73	17·21	11·21	4·65	18·93	32·13	35·24	38·70
3 and 3	28·75	5·40	8·78	5·79	23·68	17·33	11·59	4·43	19·06	31·81	35·29	38·75
4 and 4	28·86	5·06	9·11	5·61	23·72	17·53	12·27	4·28	18·74	31·68	35·22	38·55
5 and 5	28·83	5·16	9·25	5·32	23·77	17·86	13·13	4·38	18·96	31·83	35·13	38·25
6 and 6	28·89	5·24	9·36	5·35	23·53	17·91	13·58	4·45	19·71	31·83	35·25	38·55
7 and 7	28·81	5·12	9·43	5·32	23·74	17·82	13·82	3·96	19·72	31·93	35·25	38·20
8 and 8	28·80	5·12	9·36	5·25	23·90	17·57	13·56	4·21	19·64	31·88	35·37	38·10
9 and 9	28·69	4·86	9·18	5·35	23·97	17·18	12·79	4·51	19·69	31·98	35·30	38·35
10 and 10	28·78	5·14	9·43	5·13	24·00	17·03	12·21	5·08	19·40	31·96	35·37	38·15
11 and 11	28·88	5·41	9·33	5·29	23·82	17·03	11·83	5·55	19·24	32·15	35·31	38·35
12 and 12	28·83	5·58	9·48	5·61	23·87	17·00	11·50	5·51	19·32	32·01	35·11	38·85
Means ..	+28·813	+ 5·309	− 9·223	− 5·441	−23·787	−17·373	−12·392	+ 4·661	+19·306	+31·941	+35·240	+38·441

TABLE V.—Showing the Mean Temperature of every Hour for each Season, for the Summer and Winter halves of the year, and for the whole Year, without intercalating the last 21 days of August. H. M. Ship 'Plover,' Point Barrow.

1852–3.				
Hour.	Autumn. Sept., Oct., Nov.	Winter. Dec., Jan., Feb.	Spring. Mar., April, May.	Summer. June, July, Aug. 10th.
A.M. 1	+ 7·96	−15·86	− 0·51	+31·38
2	8·11	15·95	0·91	31·42
3	8·05	16·07	0·99	31·52
4	8·04	16·07	0·84	31·66
5	8·11	15·76	0·38	32·35
6	8·16	15·55	+ 0·98	32·98
7	8·17	15·47	2·20	33·69
8	8·21	15·42	3·73	34·50
9	8·44	15·35	5·47	35·15
10	8·76	15·21	6·91	35·86
11	9·08	15·02	8·14	36·53
Noon. 12	9·19	14·97	8·77	36·74
P.M. 1	9·08	14·86	9·05	37·17
2	9·90	14·96	9·15	37·41
3	8·70	15·02	8·91	37·09
4	8·43	15·04	7·88	36·73
5	8·32	15·36	7·27	36·00
6	8·29	15·51	6·05	35·56
7	8·09	15·65	4·36	34·84
8	8·09	15·61	3·12	34·05
9	7·73	15·53	2·13	33·50
10	7·50	15·45	1·25	32·79
11	7·50	15·63	0·47	32·24
12	7·36	15·91	0·09	31·91
Means ..	+ 8·268	−15·472	+ 3·851	+34·297

1852–3.		
Hour.	Winter. Sept. to Feb., 181 days.	Summer. Mar. to Aug., 163 days.
A.M. 1	− 3·88	+13·43
2	3·85	13·17
3	3·94	13·17
4	3·95	13·32
5	3·76	13·87
6	3·63	14·92
7	3·58	15·92
8	3·54	17·14
9	3·39	18·39
10	3·15	19·52
11	2·90	20·50
Noon. 12	3·82	29·95
P.M. 1	2·82	21·28
2	2·91	21·46
3	3·05	21·18
4	3·24	20·50
5	3·46	19·75
6	3·55	18·90
7	3·71	17·63
8	3·69	16·59
9	3·83	15·76
10	3·91	14·98
11	4·00	14·30
12	4·21	13·95
Means ..	− 3·537	+17·113

1852–3.	
Hour.	Year of 344 days.
A.M. 1	+ 4·29
2	4·21
3	4·16
4	4·23
5	4·59
6	5·15
7	5·65
8	6·25
9	6·93
10	7·58
11	8·19
Noon. 12	8·44
P.M. 1	8·60
2	8·60
3	8·43
4	8·01
5	7·55
6	7·09
7	6·40
8	5·92
9	5·46
10	5·04
11	4·67
12	4·39
Mean ..	+ 6·250

TABLE VI.—Showing the Mean Temperature of every Pair of similar Hours for each Season, the Half Years, and the Year.

H. M. Ship 'Plover,' Point Barrow.

Hours.	1852–3. Autumn.	Winter.	Spring.	Summer.
A.M. P.M. 1 and 1	+ 8·52	−15·36	+ 4·27	+34·27
2 and 2	8·50	15·46	4·12	34·41
3 and 3	8·41	15·55	3·96	34·31
4 and 4	8·23	15·56	3·52	34·19
5 and 5	8·21	15·56	3·44	34·17
6 and 6	8·22	15·53	3·51	34·27
7 and 7	8·13	15·56	3·28	34·26
8 and 8	8·15	15·51	3·42	34·28
9 and 9	8·08	15·44	3·79	34·33
10 and 10	8·13	15·33	4·08	34·32
11 and 11	8·28	15·32	4·30	34·38
12 and 12	8·28	15·44	4·43	34·33
Means ..	+ 8·268	−15·472	+ 3·851	+34·297

Hours.	1852–3. Winter half.	Summer half.
A.M. P.M. 1 and 1	− 3·35	+17·35
2 and 2	3·41	17·31
3 and 3	3·49	17·18
4 and 4	3·59	16·91
5 and 5	3·51	16·83
6 and 6	3·59	16·91
7 and 7	3·64	16·77
8 and 8	3·61	16·86
9 and 9	3·61	17·09
10 and 10	3·53	17·25
11 and 11	3·45	17·40
12 and 12	3·51	17·45
Means ..	− 3·537	+17·113

Hours.	1852–3. Year of 344 days.
A.M. P.M. 1 and 1	+ 6·45
2 and 2	6·41
3 and 3	6·30
4 and 4	6·12
5 and 5	6·07
6 and 6	6·12
7 and 7	6·02
8 and 8	6·08
9 and 9	6·20
10 and 10	6·31
11 and 11	6·43
12 and 12	6·42
Mean....	+ 6·250

TABLE VII.—Containing the Daily, Ten-daily, and Monthly Mean Temperatures for One Year, from hourly observations made on board H. M. S. 'Plover,' at Point Barrow. Lat. 71° 21′ N.; Long. 156° 17′ W.

Day.	1853.				1854.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
1	+33·62	+11·00	−10·33	−15·87	−25·00	−32·62	−11·29	− 2·08	+ 7·66	+41·16	+32·45	....
2	32·25	8·25	+ 6·92	15·50	22·29	34·75	12·12	+ 0·66	10·16	37·75	31·83	....
3	32·54	5·79	− 0·96	13·70	+ 2·04	37·08	14·25	2·00	12·37	37·41	32·08	....
4	31·33	1·87	+ 4·12	22·58	− 8·58	28·20	12·95	0·87	10·70	39·54	35·63	....
5	37·45	3·37	− 5·08	29·12	11·25	25·12	7·91	1·91	6·00	32·37	39·79	....
6	35·84	3·95	15·42	17·95	+ 1·12	37·83	3·29	− 1·37	4·37	32·16	40·20	....
7	31·46	9·66	3·75	11·95	−21·58	43·04	8·95	5·91	7·62	33·08	38·41	....
8	31·04	12·04	3·71	17·33	28·50	43·45	12·45	6·41	7·66	29·83	35·87	....
9	29·95	10·58	+ 8·33	33·45	27·50	42·41	20·62	6·16	11·16	27·58	36·33	....
10	25·46	5·66	−14·96	28·75	4·75	42·70	23·87	5·96	10·04	28·25	38·66	....
Means ..	+32·146	+ 7·221	− 3·533	−30·625	−14·633	−36·725	−12·775	− 2·245	+ 8·779	+33·916	+36·129	+40·00
11	33·04	0·50	10·50	34·75	+ 5·91	36·25	14·12	+ 0·41	14·41	32·00	36·66	....
12	24·71	− 0·46	14·67	31·47	19·12	24·33	20·95	3·66	21·66	33·91	34·78	....
13	24·16	+ 0·54	20·75	30·29	−13·87	12·79	20·70	− 2·20	26·50	29·66	36·41	....
14	23·96	− 0·08	15·17	35·33	+16·58	30·25	19·75	+ 7·79	26·91	28·87	41·16	....
15	22·89	0·12	17·04	18·91	−11·25	34·95	27·66	2·89	33·41	28·87	40·25	....
16	23·29	2·75	20·25	18·00	7·75	31·12	32·12	2·37	27·50	26·50	35·41	....
17	24·96	+ 4·12	0·46	24·70	+ 8·83	18·50	35·08	8·83	29·56	26·66	35·29	....
18	24·83	5·79	12·04	26·83	− 6·16	28·62	34·04	6·66	28·87	28·58	36·29	....
19	25·25	− 5·21	4·36	18·50	16·50	36·66	32·62	3·00	23·37	32·70	41·91	....
20	24·87	4·96	3·96	5·08	7·20	29·12	28·95	1·12	23·20	33·16	44·66	....
Means ..	+24·196	− 0·263	−11·951	−24·383	− 1·229	−28·262	−26·604	+ 3·454	+25·545	+30·095	+38·287	+40·00

21	+24·62	− 5·54	−20·16	− 0·29	−16·66	−28·25	−26·50	+ 7·37	+25·58	+37·95	....	....
22	27·08	7·25	9·83	4·91	14·62	25·25	23·12	7·25	26·66	36·62	....	....
23	19·75	4·04	+ 0·28	14·91	20·25	20·58	19·20	13·54	26·41	34·83	....	....
24	11·75	3·21	3·16	20·00	32·75	14·83	28·87	2·29	25·95	34·37	....	....
25	14·96	6·50	−12·91	22·25	19·79	12·87	18·91	4·58	25·91	34·79	....	....
26	11·37	10·91	+ 2·62	21·83	17·54	9·91	10·75	1·00	23·33	32·15	....	....
27	3·21	7·35	2·33	19·62	35·12	6·79	+ 7·66	3·33	26·95	29·58	....	....
28	4·46	15·04	−11·50	19·08	29·16	6·75	10·12	6·00	29·83	33·12	....	44·70
29	0·50	7·79	15·45	22·00	27·04	....	−13·33	5·08	32·79	32·87	....	37·08
30	7·33	12·29	16·50	27·79	25·54	....	14·04	8·16	30·16	31·00	....	34·12
31	....	18·04	....	28·75	26·70	....	1·37	....	34·62	....	....	42·04
Mean	+13·003	− 8·905	− 7·804	−20·145	−26·520	−15·656	−12·030	+ 5·862	+30·625	+33·729	+39·000	+39·448
Monthly mean.	+23·115	− 0·915	− 7·762	−21·010	−13·673	−27·683	−16·971	+ 2·356	+20·951	+32·580	+37·805	+39·816

By intercalating the temperatures of the 38 days' interval in July and August, at the rates given for the four decades, the Mean Temperature of the Year would be:—Sum of observations +86178, −34039, ÷8760,=5°·951 Fahr.

TABLE VIII.—Containing the Highest and Lowest Temperatures for each Month, the Means of the Daily Maxima and Minima for each Month, and the Means of these or of the Extreme Daily Temperatures; from the 'Plover's' Register, Point Barrow, 1853–54.

Month.	Highest temperature in the month.	Lowest temperature in the month.	Means of daily Maxima.	Means of daily Minima.	Means of the extremes.
1853. September..	+41	− 3	+26·03	+20·10	+23·06
October ..	14	22	3·45	− 5·09	− 0·82
November..	22	26	0·50	15·35	7·38
December..	7	40	−16·41	21·02	18·72
1854. January ..	27	37	6·03	21·35	13·67
February ..	− 3	45	23·25	32·64	27·94
March	+23	42	10·25	25·45	17·85
April	26	17	+ 9·93	6·76	+ 1·58
May	42	3	26·03	+15·00	20·51
June	47	+24	36·20	29·36	32·78
July	51	28	42·05	32·40	37·22
August	48	29	43·50	34·75	39·12
Means	+28·750	+12·833	+10·970	+ 0·328	+ 5·657

The highest single temperature occurred 20th July, and was +51°.

The lowest single temperature occurred 8th to 10th February, and was −45°.

The extreme range for the year therefore was 96°.

And the mean of these extremes was +3°.

TABLE IX.—Showing the Mean Temperature of every Hour for each Month, from hourly observations made on board the 'Plover' at Point Barrow. Lat. 71° 21′ N.; Long. 156° 17′ W.

Hour.	1853.				1854.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	Jun	July.	August.
A.M. 1	+23.40	− 1.35	− 7.80	−20.90	−14.61	−28.82	−20.90	− 3.50	+16.45	+30.53	+34.00	+36.20
2	23.20	1.19	7.23	21.25	14.51	28.74	20.93	3.56	16.48	30.53	33.85	36.30
3	22.97	1.39	7.10	21.12	14.29	28.39	20.61	3.60	16.71	30.63	34.15	36.20
4	22.77	1.42	7.23	20.90	13.80	28.07	20.22	3.56	17.45	30.90	34.55	36.00
5	22.33	1.45	7.10	20.64	13.61	27.71	20.48	2.56	18.26	31.53	35.05	36.30
6	22.40	1.35	7.10	20.87	13.48	27.53	20.22	0.60	19.26	31.93	36.95	36.70
7	22.90	1.22	7.27	20.90	13.00	27.75	19.06	+ 1.43	20.77	32.33	37.95	37.30
8	23.03	1.03	7.67	20.70	12.80	27.92	17.03	3.36	21.77	33.36	38.75	37.80
9	23.30	0.42	7.73	20.67	12.84	27.78	15.49	4.86	22.61	33.76	39.15	38.80
10	23.63	0.09	7.70	20.77	12.93	27.35	13.87	6.56	23.48	33.86	40.00	38.90
11	23.70	+ 0.26	7.87	20.61	12.98	26.89	12.51	7.63	24.26	34.16	40.00	39.70
Noon. 12	23.77	0.45	8.17	20.94	13.09	26.57	11.97	8.73	24.35	34.46	39.70	40.90
P.M. 1	23.77	0.68	7.67	21.32	12.90	26.64	11.64	9.04	24.87	34.53	39.65	40.80
2	23.83	0.45	7.73	21.35	13.25	26.60	11.34	8.70	24.45	35.00	39.50	41.10
3	23.77	− 0.32	7.83	21.16	13.28	27.00	12.29	8.10	24.19	34.73	39.05	41.30
4	23.73	0.93	7.97	21.35	13.45	27.21	12.90	7.86	24.09	34.56	38.55	41.10
5	23.20	1.26	8.17	21.29	13.77	27.53	14.09	6.70	23.61	34.06	38.50	40.20
6	22.97	1.45	8.50	21.22	13.95	27.75	15.61	4.83	23.03	33.10	38.35	40.40
7	22.67	1.52	8.40	21.12	14.29	27.78	17.61	2.63	21.84	32.26	38.10	30.10
8	22.63	1.52	8.20	21.09	14.06	28.00	18.55	0.86	20.84	32.10	37.00	38.40
9	22.70	1.52	8.00	21.06	14.38	28.17	19.13	− 0.63	19.64	31.43	35.95	37.90
10	22.73	1.29	8.03	21.09	14.32	28.03	19.80	1.60	18.74	31.00	35.15	37.40
11	22.77	1.35	7.97	21.03	14.32	28.03	20.00	2.30	18.38	30.76	34.50	37.00
12	22.60	1.71	7.87	20.93	14.16	27.85	20.58	2.86	17.58	30.33	34.60	36.80
Means ..	+23.115	− 0.915	− 7.762	−21.010	−13.673	−27.683	−16.971	+ 2.356	+20.951	+32.580	+37.258	+38.441

TABLE X.—Showing the Mean Temperature of every Pair of similar Hours for each Month (and for comparison the Mean of each Month repeated), from the 'Plover's' Register at Point Barrow.

Hours.	1853.				1854.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
A.M. P.M. 1 and 1	+23·55	− 0·33	− 7·73	−21·11	−13·75	−27·73	−16·26	+ 2·78	+20·66	+32·53	+36·82	+38·50
2 and 2	23·52	0·37	7·48	21·30	13·88	27·67	16·38	2·56	20·46	32·76	36·67	38·70
3 and 3	23·36	0·85	7·47	21·13	13·79	27·69	16·45	2·25	20·45	32·68	36·60	38·25
4 and 4	23·25	1·17	7·60	21·13	13·65	27·64	16·56	2·15	20·77	32·73	36·55	38·55
5 and 5	22·77	1·35	7·63	20·97	13·69	27·62	17·29	2·07	20·93	32·80	36·77	38·25
6 and 6	22·68	1·40	7·80	21·04	13·71	27·64	17·91	2·11	21·14	32·51	37·65	38·55
7 and 7	22·78	1·37	7·83	21·01	13·64	27·76	18·33	2·03	21·30	32·30	38·02	38·20
8 and 8	22·83	1·27	7·93	20·91	13·45	27·96	17·79	2·11	21·30	32·73	37·87	38·10
9 and 9	23·00	0·96	7·87	20·87	13·61	27·98	17·27	2·11	21·12	32·60	37·55	38·35
10 and 10	23·18	0·69	7·87	20·93	13·62	27·69	16·83	2·48	21·11	32·43	37·57	38·15
11 and 11	23·23	0·54	7·93	20·82	13·65	27·46	16·25	2·66	21·32	32·46	37·25	38·35
12 and 12	23·18	0·63	8·01	20·93	13·62	27·21	16·27	2·93	20·96	32·40	37·15	38·85
Means ..	+23·115	− 0·915	− 7·762	−21·010	−13·673	−27·685	−16·971	+ 2·356	+20·951	+32·580	+37·205	+38·400

TABLE XI.—Showing the Mean Temperature of every Hour for each Season, for the Summer and Winter halves of the year, and for the whole Year (without intercalating the last 11 days of July or any part of August). H. M. S. 'Plover,' Point Barrow.

1853–4.				
Hour.	Autumn. Sept., Oct., Nov.	Winter. Dec., Jan., Feb.	Spring. March, April, May.	Summer. June, July, 50 days.
A.M. 1	+ 4·68	−21·20	− 2·40	+31·92
2	4·85	21·23	2·40	31·86
3	4·76	21·03	2·13	32·04
4	4·63	20·68	1·83	32·36
5	4·53	20·42	1·30	32·94
6	4·58	20·40	0·39	33·94
7	4·73	20·31	+ 1·08	34·58
8	4·60	20·24	2·69	35·52
9	5·09	20·18	4·01	35·92
10	5·22	20·12	5·38	36·32
11	5·30	19·93	6·44	36·50
Noon. 12	5·29	19·98	7·02	36·56
P.M. 1	5·53	20·07	7·41	36·58
2	5·35	20·20	7·09	36·80
3	5·14	20·26	6·65	36·46
4	4·88	20·45	6·33	36·16
5	4·54	20·65	5·39	35·84
6	4·27	20·74	4·14	35·20
7	4·18	20·93	2·43	34·60
8	4·13	20·93	1·27	34·06
9	4·33	20·97	0·29	33·24
10	4·41	20·92	− 1·53	32·66
11	4·41	20·80	1·09	32·26
12	4·16	20·75	1·79	32·04
Means ..	+ 4·750	−20·561	− 2·241	+34·431

1853–4.		
Hour.	Winter Half-year.	Summer Half, 142 days.
A.M. 1	− 8·18	+ 9·68
2	8·11	9·66
3	8·06	9·90
4	7·95	10·20
5	7·88	10·75
6	7·84	11·69
7	7·71	12·88
8	7·69	14·25
9	7·52	15·24
10	7·38	16·27
11	7·24	17·02
Noon. 12	7·27	17·42
P.M. 1	7·20	17·68
2	7·30	17·54
3	7·49	17·14
4	7·78	16·83
5	7·98	15·40
6	8·17	14·37
7	8·30	13·76
8	8·27	12·81
9	8·25	11·82
10	8·18	11·15
11	8·12	10·64
12	8·17	10·12
Means ..	− 7·836	+13·566

1853–4.	
Hour.	Year of 323 days.
A.M. 1	− 0·33
2	0·30
3	0·16
4	+ 0·02
5	0·31
6	0·74
7	1·33
8	1·95
9	2·48
10	3·01
11	3·42
Noon. 12	3·58
P.M. 1	3·73
2	3·62
3	3·34
4	3·07
5	2·60
6	2·05
7	1·39
8	0·99
9	0·60
10	0·31
11	0·13
12	− 0·13
Mean	+ 1·577

TABLE XII.—Showing the Mean Temperature of every Pair of similar Hours for each Season, the Half Years, and the Year.

H. M. S. 'Plover,' Point Barrow.

1853–4.				
Hours. A.M. P.M.	Autumn.	Winter.	Spring.	Summer, 50 days.
1 and 1	+ 5·11	−20·64	+ 2·50	+34·25
2 and 2	5·16	20·71	2·34	34·33
3 and 3	4·95	20·65	2·26	34·25
4 and 4	4·76	20·57	2·25	34·26
5 and 5	4·52	20·53	2·04	34·39
6 and 6	4·42	20·57	1·87	34·57
7 and 7	4·46	20·62	1·76	34·59
8 and 8	4·37	20·59	1·98	34·79
9 and 9	4·66	20·58	2·15	34·58
10 and 10	4·81	20·52	2·42	34·49
11 and 11	4·86	20·36	2·67	34·38
12 and 12	4·78	20·37	2·61	34·30
Means ..	+ 4·750	−20·561	+ 2·241	+34·431

1853–4.		
Hours. A.M. P.M.	Winter half.	Summer half, 142 days.
1 and 1	− 7·69	+13·68
2 and 2	7·70	13·60
3 and 3	7·77	13·52
4 and 4	7·83	13·52
5 and 5	7·93	13·43
6 and 6	8·00	13·38
7 and 7	8·01	13·32
8 and 8	7·98	13·53
9 and 9	7·88	13·57
10 and 10	7·78	13·71
11 and 11	7·68	13·83
12 and 12	7·72	13·77
Means ..	− 7·836	+13·566

1853–4.	
Hours. A.M. P.M.	Year of 323 days.
1 and 1	+ 1·70
2 and 2	1·66
3 and 3	1·58
4 and 4	1·55
5 and 5	1·45
6 and 6	1·40
7 and 7	1·36
8 and 8	1·47
9 and 9	1·54
10 and 10	1·66
11 and 11	1·77
12 and 12	1·72
Mean	+ 1·577

TABLE XIII.—Showing the Mean Temperature of each Month, and the Mean of each "Decade" or third part of a Month for the Two Years, at Point Barrow. Also the Highest and Lowest single Temperatures, the Mean of these, and the Extreme Range of the Thermometer, observed during the same period; and the Mean Temperature of the whole 24 Months, deduced from the aggregate sum of the observations.

Means of	1852–53.				1853–54.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
1st decade	+33·44	+ 8·35	− 2·68	−21·59	−18·38	−25·24	−11·55	− 6·88	+11·35	+32·04	+34·35	+39·22
2nd decade	27·44	1·29	13·95	12·48	14·85	25·58	23·90	+ 6·26	22·50	30·84	36·64	38·50
3rd decade	17·01	− 2·58	8·83	6·92	23·77	13·81	18·32	11·14	27·33	33·89	38·43	37·72
Whole Month ..	+25·964	+ 2·197	− 8·492	−13·225	−18·730	−22·528	−14·681	+ 3·508	+20·128	+32·260	+36·522	+38·158

Highest single temperature during two years occurred 31st July 1853 .... +52°
Lowest single temperature during two years occurred 8th to 10th February 1854 .... −45°
Extreme range of Thermometer during the two years .... 97°
Mean of these two extremes +3°·5.

Mean temperature of the Air for the two years at Point Barrow, deduced from the sums of the hourly observations, those of the months of July and August having been intercalated:—

1852–53. 1853–54.
Sums, +68519 +52139 = +120628, ÷17520 = +6°·886 Mean temp.

TABLE XIV.—Showing the Mean Temperature of every Hour for each Month, the Mean of Two Years from hourly observations made on board the 'Plover' at Point Barrow. Lat. 71° 21′ N.; Long. 156° 17′ W.

Hour.	1852–53.				1853–54.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
A.M. 1	+25·94	+ 1·61	− 8·43	−13·48	−19·12	−23·46	−18·06	− 2·03	+15·19	+29·39	+33·22	+36·22
2	25·82	1·82	8·03	13·70	18·99	23·60	18·25	2·26	15·14	29·34	33·72	36·32
3	25·68	1·50	7·86	13·83	18·75	23·50	18·30	2·28	15·35	29·51	33·89	36·22
4	25·61	1·38	7·81	13·67	18·54	23·41	18·15	2·24	15·98	29·75	34·18	36·02
5	25·51	1·45	7·85	13·20	18·45	23·10	18·40	1·59	16·88	30·64	34·61	36·32
6	25·65	1·61	8·00	13·21	18·37	22·82	17·91	+ 0·08	18·51	31·26	35·82	36·72
7	25·90	1·74	8·11	13·24	18·17	22·73	16·88	1·78	19·98	31·94	36·56	37·32
8	25·96	1·98	8·41	13·17	18·12	22·62	15·20	3·81	21·04	32·89	37·40	37·82
9	26·07	2·53	8·31	13·12	18·34	22·28	13·52	5·48	22·22	33·51	37·77	38·82
10	26·35	3·03	8·28	13·03	18·43	21·93	11·82	7·16	23·12	34·01	38·55	38·92
11	26·47	3·53	8·30	12·98	18·31	21·53	10·59	8·61	23·90	34·66	38·72	39·72
Noon. 12	26·59	3·87	8·60	13·19	18·30	21·32	9·87	9·34	24·25	34·86	38·57	40·92
P.M. 1	26·27	3·89	8·28	13·22	18·32	21·23	9·48	9·68	24·53	35·19	38·75	40·82
2	26·48	3·57	8·39	13·22	18·59	21·28	9·33	9·48	24·25	35·55	38·79	41·12
3	26·43	2·98	8·40	13·09	18·70	21·50	9·69	8·96	24·15	34·98	38·60	41·32
4	26·50	2·50	8·90	13·06	18·80	21·76	10·67	8·68	23·53	34·66	38·18	41·12
5	26·08	2·35	9·03	13·08	18·98	22·37	12·01	8·05	23·01	33·98	37·88	40·22
6	25·92	2·22	9·16	13·19	18·90	22·73	13·57	6·96	22·33	33·08	37·68	40·42
7	25·68	2·01	9·15	13·09	19·24	22·85	15·27	4·21	21·04	32·28	37·31	39·12
8	25·66	1·86	8·83	12·98	19·20	22·91	16·14	2·51	19·91	31·71	36·44	38·42
9	25·62	1·36	8·73	13·09	19·23	22·87	16·59	1·15	18·57	31·06	35·67	37·92
10	25·61	1·41	9·61	13·03	19·19	22·78	17·22	0·40	17·38	30·38	34·98	37·42
11	25·64	1·34	8·95	13·12	19·16	22·96	17·50	− 0·40	16·65	29·94	34·44	37·02
12	25·42	1·08	8·90	13·35	19·19	22·89	17·90	0·90	16·03	29·54	34·29	36·82
Means ..	+25·964	+ 2·197	− 8·492	−13·225	−18·730	−22·528	−14·681	+ 3·508	+20·128	+32·260	+36·522	+38·158

TABLE XV.—Showing the Mean Temperature of every Pair of similar Hours for each Month, being the Means of Two Years, from the 'Plover's' Register at Point Barrow.

Hours.	1852–53.				1853–54.							
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
A.M. P.M. 1 and 1	+26·20	+ 2·75	− 8·35	−13·35	−18·72	−22·34	−13·77	+ 3·82	+19·86	+32·29	+36·23	+38·52
2 and 2	26·15	2·69	8·21	13·46	18·79	22·44	13·79	3·61	19·69	32·44	36·25	38·72
3 and 3	26·05	2·27	8·13	13·46	18·72	22·50	13·99	3·34	19·75	32·25	36·24	38·77
4 and 4	26·05	1·94	8·35	13·36	18·67	22·58	14·41	3·22	19·75	32·20	36·18	38·57
5 and 5	25·79	1·90	8·44	13·14	18·71	22·73	15·20	3·23	19·94	32·31	35·74	38·27
6 and 6	25·78	1·91	8·58	13·20	18·63	22·77	15·74	3·27	20·42	32·17	36·75	38·57
7 and 7	25·79	1·87	8·64	13·16	18·70	22·79	16·07	2·99	20·51	32·11	36·93	38·22
8 and 8	25·81	1·93	8·67	13·07	18·66	22·76	15·67	3·16	20·47	32·30	36·92	38·12
9 and 9	25·84	1·94	8·52	13·10	18·78	22·57	15·05	3·31	20·39	32·28	36·72	38·37
10 and 10	25·98	2·22	8·64	13·03	18·81	22·35	14·52	3·78	20·25	32·19	36·77	38·17
11 and 11	26·05	2·23	8·62	13·05	18·73	22·24	13·89	4·10	20·27	32·30	36·58	38·37
12 and 12	26·00	2·47	8·75	13·27	18·74	22·10	13·88	4·24	20·14	32·20	36·43	38·87
Means ..	+25·964	+ 2·197	− 8·492	−13·225	−18·730	−22·528	−14·681	+ 3·508	+20·128	+32·260	+36·522	+38·158

TABLE XVI.—Being the Mean of Two Years, showing the Mean Temperature of every Hour for each Season, for the Summer and Winter Halves of the Year, and for the whole Year, the omissions in July and August being intercalated. 'Plover,' Point Barrow.

1852–54.				
Hour.	Autumn. Sept., Oct., Nov.	Winter. Dec., Jan., Feb.	Spring. March, April, May.	Summer. June, July, Aug.
A.M. 1	+ 6·32	−18·53	− 1·46	+32·90
2	6·48	18·59	1·65	32·89
3	6·40	18·55	1·55	33·03
4	6·33	18·38	1·33	33·26
5	6·31	18·09	0·84	33·90
6	6·36	17·97	+ 0·29	34·71
7	6·45	17·89	1·64	35·39
8	6·46	17·83	3·21	36·26
9	6·72	17·77	4·74	36·79
10	6·98	17·66	6·14	37·34
11	7·18	17·47	7·24	37·77
Noon. 12	7·24	17·48	7·89	37·90
P.M. 1	7·31	17·47	8·24	38·13
2	7·18	17·58	8·12	38·36
3	6·96	17·64	7·78	38·03
4	6·65	17·75	7·16	37·70
5	6·43	18·00	6·33	37·17
6	6·28	18·12	5·09	36·63
7	6·13	18·29	3·40	35·97
8	6·07	18·27	2·19	35·33
9	6·03	18·25	1·21	34·63
10	5·95	18·18	0·25	33·98
11	5·95	18·21	− 0·26	33·50
12	5·81	18·33	0·44	33·23
Means ..	+ 6·508	−18·017	+ 3·046	+35·616

1852–54.		
Hours.	Winter half.	Summer half.
A.M. 1	− 6·03	+15·72
2	5·98	15·62
3	6·00	15·74
4	5·95	15·96
5	5·82	16·53
6	5·74	17·50
7	5·64	18·51
8	5·61	19·73
9	5·45	20·76
10	5·27	21·74
11	5·07	22·50
Noon. 12	5·05	22·89
P.M. 1	5·01	23·18
2	5·13	23·24
3	5·27	22·90
4	5·47	22·43
5	5·72	21·75
6	5·86	20·86
7	6·01	19·68
8	5·98	18·76
9	6·04	17·92
10	6·05	17·11
11	6·06	16·62
12	6·19	16·39
Means ..	− 5·686	+19·325

1852–54.	
Hours.	Whole year of 365 days.
A.M. 1	+ 4·84
2	4·82
3	4·87
4	5·00
5	5·35
6	5·88
7	6·43
8	7·06
9	7·65
10	8·23
11	8·72
Noon. 12	8·92
P.M. 1	9·06
2	9·05
3	8·81
4	8·48
5	8·02
6	7·50
7	6·84
8	6·39
9	5·94
10	5·58
11	5·28
12	5·10
Mean ..	+ 6·821

TABLE XVII.—Two Years, showing the Mean Temperature of every Pair of similar Hours for each Season, the Half Years and the Year. H. M. S. 'Plover,' Point Barrow.

1852–54.				
Hours.	Autumn.	Winter.	Spring.	Summer.
A.M. P.M. 1 and 1	+ 6.81	−18.00	+ 3.38	+35.51
2 and 2	6.83	18.08	3.23	35.62
3 and 3	6.68	18.10	3.11	35.53
4 and 4	6.49	18.06	2.91	35.48
5 and 5	6.37	18.05	2.74	35.53
6 and 6	6.32	18.09	2.69	35.67
7 and 7	6.29	18.05	2.52	35.68
8 and 8	6.31	18.05	2.70	35.78
9 and 9	6.37	18.09	2.97	35.70
10 and 10	6.47	17.92	3.25	35.66
11 and 11	6.56	17.84	3.49	35.63
12 and 12	6.53	17.90	3.52	35.56
Means ..	+ 6.508	−18.017	+ 3.046	+35.616

1852–54.		
Hours.	Winter half.	Summer half.
A.M. P.M. 1 and 1	− 5.52	+19.45
2 and 2	5.55	19.43
3 and 3	5.63	19.32
4 and 4	5.71	19.20
5 and 5	5.77	19.14
6 and 6	5.79	19.13
7 and 7	5.83	19.10
8 and 8	5.80	19.24
9 and 9	5.75	19.34
10 and 10	5.66	19.42
11 and 11	5.56	19.56
12 and 12	5.62	19.64
Means ..	− 5.686	+19.335

1852–54.	
Hours.	Year.
A.M. P.M. 1 and 1	+ 6.96
2 and 2	6.94
3 and 3	6.84
4 and 4	6.74
5 and 5	6.68
6 and 6	6.67
7 and 7	6.03
8 and 8	6.72
9 and 9	6.79
10 and 10	6.88
11 and 11	7.00
12 and 12	7.01
Mean ..	+ 6.821

TABLE XVIII.—Showing the Mean Temperature of every Hour for the month of June, part of the month of July and for June, and the twelve first days of July combined, from observations taken hourly with a blackened Thermometer at the 'Plover's' winter quarters, Point Barrow.

Hour.	1853. June.	1853. July 22nd.	1853. 42 days of June and July.
A.M. 1	34·50	+35·72	+35·02
2	36·26	36·90	36·85
3	38·66	39·09	39·62
4	43·43	42·54	44·19
5	48·66	43·31	48·14
6	53·90	46·59	53·28
7	59·26	52·59	58·57
8	63·00	54·90	61·92
9	66·00	58·36	64·67
10	67·66	62·31	65·21
11	72·03	65·00	70·36
Noon. 12	71·86	64·99	70·30
P.M. 1	72·16	63·31	69·83
2	71·43	62·72	69·30
3	69·40	65·81	68·21
4	67·56	63·18	65·95
5	63·14	56·13	61·07
6	58·10	50·68	56·04
7	54·13	52·09	53·38
8	49·06	46·13	48·40
9	47·06	37·31	45·45
10	42·26	37·40	41·26
11	37·20	35·63	37·12
12	36·16	34·54	35·95
Means	54·994	....	54·120

TABLE XIX.—Showing the Mean Temperature of every Pair of similar Hours in first and third columns of Table XVIII.

Hours. A.M. P.M.	1853. June.	1853. July 22nd.	1853. June and July.
1 and 1	+53·33	....	+52·42
2 and 2	53·85	....	52·57
3 and 3	54·03	....	53·41
4 and 4	55·50	....	54·57
5 and 5	54·50	....	54·55
6 and 6	56·00	....	54·86
7 and 7	56·70	....	55·47
8 and 8	56·03	....	55·16
9 and 9	56·53	....	55·06
10 and 10	54·80	....	53·23
11 and 11	54·61	....	53·71
12 and 12	54·01	....	53·12
Means	54·994	....	54·120

Highest single temperature in the sun +106° on 7th June 1853.

Explanation of Plate II.

Fig. 1 represents the mean daily curve for each month, as deduced from Table XIV. From among the almost straight lines representing the winter months, March is observed to rise in a bold curve, showing the rapidly increasing power of the solar rays, which had hardly produced any effect in shaded places during February. April exceeds March by 2 degrees in the height of its curve; but that of each summer month in succession becomes flatter in consequence of the summer warmth being attended by more cloudy weather, and a lessened fall of temperature during the nights. September presents a curve of great flatness, the difference of temperature between noon and midnight scarcely exceeding 1 degree. The almost continued foggy state of the weather then prevents the sun effecting much rise in the day, and the great extent of sea, river, and lake surface, still unfrozen during the earlier part of the month, prevents any great fall of temperature during the night. With the exception of a slight rise in the October curve, the whole six representing autumn and winter are remarkably flat.

Fig. 2 shows the mean daily curves of the four seasons, deduced from Table XVI.; also the curve of the winter half of the year, or the autumn and winter combined, the curve of the summer half, which is spring and summer combined, and the curve of the whole year, each being the mean of two years. The flat curve of autumn has nearly the same form as September, and in position occupies the place of the mean temperature of the year. The winter line nearly coincides both in form and position with January, and is very flat. Spring has nearly the form of March and the position of April; and the summer curve, either in shape or position, does not differ much from July. With the exception of autumn, the curve of each season bears a striking resemblance to that of its middle month.

Fig. 3 indicates the curve of mean daily temperature shown by a blackened thermometer exposed to the sun. The black line represents the month of June, and the dotted one three weeks before and after the 21st of June. In both, the extremes seem to be very near noon and midnight, and the bold character of the curve is very striking.

On the Algebraic Couple; and on the Equivalents of Indeterminate Expressions. By Charles James Hargreave, *LL.D., F.R.S.*

In a paper entitled "Analytical Researches concerning Numbers," which was published in the Philosophical Magazine some years ago (vol. xxxv. p. 36), I had occasion to avail myself of a principle, which, though it has not yet taken rank amongst recognized forms of mathematical reasoning, appears to be capable of extensive application and calculated to lead to true and useful results. This principle may be expressed by stating simply, that the analytical equivalent of an indeterminate expression is the arithmetical mean of all its possible values. The accuracy of the results to which I was conducted by the application of this principle in the paper above referred to, led me to the conclusion, that the principle might probably to some extent be introduced into mathematical science, without departing from or unduly extending doctrines heretofore admitted. Since that period, I have not had the opportunity of pursuing this interesting subject; but I find that it is one

which has not failed to attract the attention of eminent mathematicians; and I trust I may be permitted to avail myself of this Meeting of the British Association in Dublin, as a convenient opportunity for the publication of the views which I had in contemplation on the occasion of my former paper. These views having suggested themselves in the course of a brief investigation relating to the interpretation of the Algebraic Couple, I propose to introduce this subject also, in the hope that it may prove interesting to those who have given their attention to the various systems of Multiple Algebra which have been from time to time propounded.

On the Geometrical Interpretation of the Algebraic Couple.

The object of this section is to apply and interpret the Algebraic Couple to and by means of the geometry of angular magnitude and position.

The couple in its ordinary form, $x+y\sqrt{-1}$, is the argument of the arbitrary function, $f(x+y\sqrt{-1})$, which represents a value of u in the partial differential equation

$$\frac{d^2u}{dx^2}+\frac{d^2u}{dy^2}=0.$$

If we take the corresponding differential equation of three variables,

$$\frac{d^2u}{dx^2}+\frac{d^2u}{dy^2}+\frac{d^2u}{dz^2}=0,$$

and effect its integration, not generally, but under the restrictive condition

$$x^2+y^2+z^2=r^2 \text{ (a constant)},$$

we obtain

$$u=\phi\left(\tan^{-1}\frac{y}{x}\pm\tan^{-1}\frac{z\sqrt{-1}}{r}\right);$$

which may be regarded as an integration of the equation upon the surface of a sphere whose radius is r. If l be the longitude of a point computed from any origin, and λ its distance in latitude from the equator, the integral assumes the form

$$u=\phi\left(l\pm\cos^{-1}\frac{1}{\cos\lambda}\right),$$

or

$$u=\phi\left(l\mp\sqrt{-1}\log\tan\frac{\mu}{2}\right),$$

where μ is the co-latitude. The argument of this function is now in the form of an ordinary algebraic couple, the constituents of which are angular magnitudes; and my object will be to show that the couple in this form is an adequate symbolical representation of position on a sphere, or of angular position in space, in the same manner as the ordinary couple adequately represents position on a plane.

It will be convenient for the sake of comparison to consider the algebraic couple, when geometrically interpreted, rather as an operation, than as a quantity or result. Let us regard $x+y\sqrt{-1}$ not merely as denoting the *position* of a point (x, y), but implying also the process of arriving at such a point from the origin by progressing along an unvarying course, viz. that course which is constantly inclined to the unit-line at an angle whose tangent is $\frac{y}{x}$.

On a plane the direction of unvarying course is the straight line; and its equation is

$$y=x\tan\beta,$$

and the symbol denoting the point (x, y), involving its distance along the unit-line, x, and the angle defining its course, β, is

$$x(1+\sqrt{-1}\tan\beta),\text{ or }\frac{x}{\cos\beta}\epsilon^{\beta\sqrt{-1}}.$$

Now if, on a sphere, we consider the equator as the unit-line on which real angles are measured, the line of unvarying course, or the line which is always inclined to the unit-line at the same angle, is the rhumb line; and its equation is

$$l\tan\theta=\log\cot\frac{\mu}{2},$$

where θ is the angle of direction. Introducing this value of θ into the couple in its new form, $l\pm\sqrt{-1}\log\cot\frac{\mu}{2}$, we obtain simply

$$l(1\pm\sqrt{-1}\tan\theta),\text{ or }\frac{l}{\cos\theta}\epsilon^{\theta\sqrt{-1}};$$

which is a couple of precisely the same form as the ordinary plane couple.

If we lay down the definitions that two lines of unvarying course (or rhumb lines) are parallel when they are inclined at the same angle to the equator, and that parallel lines are equal when they traverse the same amount of longitude, we easily obtain the proper rules for adding and multiplying two or more angular positions.

To find the sum of two positions P or (l, θ) and P$'$ or (l', θ'). From the origin O draw the unvarying courses OP and OP$'$; from P draw the course PP$''$ equal and parallel to OP$'$; then P$''$ is the resultant position. For the algebraic sum,

$$l(1\pm\sqrt{-1}\tan\theta)+l'(1\pm\sqrt{-1}\tan\theta')\text{ equals }l''(1\pm\sqrt{-1}\tan\theta''),$$

if $\qquad l+l'=l''$, and $l''\tan\theta''=l\tan\theta+l'\tan\theta'$.

Now in the construction above given, (which the reader will easily imagine without diagram,) we have

$$l''=l+l';$$

and since the equation of the line PP$''$ is

$$l'\tan\theta'=\log\cot\frac{\mu''}{2}-\log\cot\frac{\mu}{2},$$

we also have

$$l''\tan\theta''=l\tan\theta+l'\tan\theta'.$$

Similarly, to find the difference of two positions P$'$ and P$''$: from P$''$ draw the course P$''$P parallel to OP$'$ and equal to it, but in the opposite direction; then P will be the difference of the two positions.

Considering the couple in the form $\frac{l}{\cos\theta}\epsilon^{\theta\sqrt{-1}}$, it will be seen that the amplitude denotes, as on a plane, the direction of the position, or the angle defining the course; but the modulus does not denote the angular distance traversed, or the length of the course, for that is $\frac{\lambda}{\sin\theta}$; but it denotes the line into which the course would be projected if the sphere were opened out

after the fashion of Mercator's chart. The product of two positions (l, θ) and $(l'\ \theta')$, (that is, the fourth proportional to the unit of angular magnitude and the two positions,) is evidently the position (l'', θ''), where $\theta''=\theta'+\theta$, and $\frac{l''}{\cos\theta''}=\frac{l}{\cos\theta}\cdot\frac{l'}{\cos\theta'}$; that is to say, the amplitude of the product is the sum of the amplitudes of the factors; and the projection of the modulus of the product is the product of the projections of the moduli of the factors. We thus see that as a plane angle bears a sort of logarithmic relation to linear magnitude, so the dihedral angle (denoted here by θ) bears a similar logarithmic relation to plane angular magnitude.

It will be at once apparent that in this method of representing angular position, every point has an infinite number of symbolical representations, inasmuch as it may be reached from the origin by an infinite number of perfectly distinct courses. The longitude which we have denoted by l may be denoted also by any value of $l\pm 2n\pi$; each value of which has a corresponding and distinct value of θ. In effect, the couple becomes

$$\frac{l\pm 2n\pi}{\cos\theta_n}\epsilon^{\theta n\sqrt{-1}},$$

where θ_n is determined by the equation

$$(l\pm 2n\pi)\tan\theta_n=\log\cot\frac{\mu}{2}.$$

If the point be at the pole of the sphere, the values of θ_n are continuous; that is to say, every angle is a value of θ_n; which is well known, for it is obvious that the pole may be reached by an unvarying course at whatever angle we start from the equator. In this case the longitude traversed is infinite; except when θ_n is $\frac{\pi}{2}$, in which case the longitude traversed assumes the form $\infty\div\infty$, and is any arbitrary quantity. This also is geometrically evident, since if the pole be regarded as having a longitude, that longitude is perfectly arbitrary. In this case the couple assumes the form $l\left(1+\sqrt{-1}\tan\frac{\pi}{2}\right)$. Comparing this with the form we started from, $\tan^{-1}\frac{y}{x}+\tan^{-1}\frac{z\sqrt{-1}}{r}$, and remembering that at the pole $z=r$, we have $\tan^{-1}(\sqrt{-1})=\infty\sqrt{-1}$, the infinity employed being an arbitrary multiple of $\tan\frac{\pi}{2}$.

Since

$$\tan^{-1}a+\tan^{-1}(\sqrt{-1})=\tan^{-1}\frac{a+\sqrt{-1}}{1-a\sqrt{-1}}=\tan^{-1}\sqrt{-1},$$

it follows that, if either of two positions be at the pole, their sum is at the pole; unless indeed the other point be at the opposite pole, (in which case $a=-\sqrt{-1}$,) when their sum is any point on the equator, or rather every point on the equator at the same time. In like manner, since

$$\tan^{-1}a-\tan^{-1}(\sqrt{-1})=\tan^{-1}\frac{a-\sqrt{-1}}{1+a\sqrt{-1}}=\tan^{-1}(-\sqrt{-1}),$$

it follows that if a position at the pole be deducted from any other position, the resultant position is at the opposite pole; and since $n\tan^{-1}(\sqrt{-1})=\tan^{-1}(\sqrt{-1})$, the sum of any number of polar positions is a polar position.

On Infinite Angles, and on the Principle of Mean Values.

The exemplification of these subjects by the foregoing theory depends mainly on the distinction above pointed out, between considering a position merely as a point reached, and having one fixed relation with the origin, and considering it with reference to the course by which it has been reached. The former mode of consideration is merely a limiting view of the latter. If we conceive a point on a sphere starting from the origin of longitude and traversing an unvarying course inclined to the meridian, and if we at any moment inquire, first, what amount of longitude has it traversed; and secondly, in what longitude is it now posited, the answers to the two questions must obviously be, in an algebraic sense, the same; and in a geometrical sense also they must be the same wherever they are intelligible, that is, for every position from the equator up to and exclusive of the pole. The assertion of this geometrical proposition (the identity of the answers to the two queries), extended by the substitution of *inclusive* for *exclusive*, does not involve any principle other than the axiom, that, what is quantitatively true up to the limit, is quantitatively true at the limit; for in this case the passage from 'up to the limit' to 'at the limit,' may be considered in such a light as not of necessity to involve any change in the character of the subjects or ideas with which we are dealing, or to transfer our conceptions from calculable magnitude to something no longer the subject of calculation. The passage from the equator of a sphere to the pole by an unvarying course does not of necessity involve the consideration of infinite magnitude, for the linear space traversed in getting up to the pole is $\frac{\pi-\alpha}{2\sin\theta}$, where α is infinitely small; and the linear space traversed in actually attaining the pole is $\frac{\pi}{2\sin\theta}$, both of which are finite and calculable. It is true that an infinite amount of angular longitude is traversed, but this consideration does not interfere with the certainty of our actually attaining the pole in a finite time at a finite rate of progress; and there is nothing in the geometrical character of the problem which could lead us to believe that the above inquiries are of totally different natures when applied to the pole, and when applied to a point indefinitely near to the pole. Let us then consider the point as having reached the pole in this manner, and propose the two inquiries above suggested.

If we ask, what amount of longitude has been traversed; the answer is, an infinite amount. If we ask the geometrical question, in what longitude does the point now exist; the answer is, that it is in every possible longitude throughout the whole cycle of longitude.

We are thus led by these considerations to the inference that the idea (as applied to geometry) of an angle which in an analytical sense is infinite, and the idea of an angle which has at one and the same time every real magnitude, are one and the same idea. An angle in geometry, when made to vary by a uniform process, is of necessity periodic in its magnitude; but when the symbol representing an angle is imported into algebra by the introduction of its trigonometrical functions into general analysis, then the angle or its symbol must of necessity be considered as having a progressive magnitude, and as being capable of having every real value from negative infinity to positive infinity; and the foregoing considerations tend to the conclusion, that an infinite angle, in the latter sense, is the same thing as that angle in the former sense, which has at the same time and in one conception every real value; an idea, the perception of which is facilitated by the circumstance that we can geometrically depict a position whose angular distance in longitude from

a fixed origin has this singular value. If the conception of such an angle be difficult, the difficulty exists to the analyst alone: to the geometrician the idea is easy and even elementary; for to assert that the pole has at once every possible longitude, is merely to say that it is the intersection of all the meridians, or that it exists at once on every meridian, which is in truth the definition of the pole.

The considerations here developed seem to derive additional weight from a view of the subject which we have hitherto excluded; where the point passes to the pole directly in latitude, without any geometrical change of longitude; that is, the case where $\theta=\frac{\pi}{2}$. This is a limiting case. For all values of θ *up to* this value, the longitude traversed is infinite; *at* this point the infinity changes sign. What is the value through which it passes? The analytical expression for the longitude, in all cases, is

$$l=\cot\theta\log\cot\frac{\mu}{2}=\cot\frac{\pi}{2}\log\tan\frac{\pi}{2}\text{ at the pole.}$$

This then assumes the form $\infty\div\infty$, where the elements producing the two infinities are independent of each other; a kind of expression which we know to be the algebraic symbol for that which has every value within the whole range of value. It is indeed generally said to be the representative of indeterminate value, or that it means, "any real quantity we please:" but the language appears inadequate, the thing represented being manifestly, "every real quantity at once." Here then we have a case in which, without passing from the field of analysis, we find the conception of an angle having every possible value at once; and it presents itself to us as the limiting idea of a series of infinities, and as the mode of transition from a series of positive infinities to exactly the same series of negative infinities.

The series of infinite angles which represents the longitude traversed in reaching the pole, is a series of functions of θ, of such a nature that their rate of increase can be ascertained and their relative magnitudes compared, with as much ease as if they were all finite quantities; for they vary directly as cotan θ.

If ∞_θ denote the longitude of the pole as reached at the angle θ, we have

$$\frac{d(\infty_\theta)}{d\theta}=-\frac{\log\cot\frac{\mu}{2}}{\sin^2\theta}=-\frac{l\tan\theta}{\sin^2\theta}=-\frac{2\infty_\theta}{\sin 2\theta};$$

an equation which marks the rate of decrease as θ advances from 0 towards $\frac{\pi}{2}$: at that point it passes through the phase of analytical indeterminateness, and then passes through the stages of negative infinity at the same rate of progress as it had manifested on the positive side. The general result may be thus recapitulated: that having in analysis met with angles of various degrees of infinite magnitude, they are interpreted geometrically into angles, each of which has at the same time every possible value; that having also in analysis met with an angle which has an absolutely indeterminate value, or all values at the same time, we find that it is the mode by which a series of decreasing positive infinite angles passes without discontinuity to an exactly similar series of negative infinite angles.

The series of infinite angles with which we are dealing is evidently at its positive maximum when $\theta=0$, and at its negative maximum when $\theta=\pi$. At these points we pass through what would appear to be the most transcendental of all infinite angles; which resolves itself in geometry into the

almost irrational idea, of the amount of longitude which it would be necessary to traverse before we reach the pole, the condition of the problem being that we are never to quit the equator. It is useful, however, not to neglect this transitional infinity, for it is evidently of a different kind from those on each side of it. It is the infinitely remote limit of a series of *increasing* infinities, just as the other transitional point appeared to be the nearest approach to finite quantity that infinity admits of, the minimum point of a series of *decreasing* infinities.

Before proceeding to consider the trigonometrical functions of ∞_θ, it will be convenient to point out another series of infinite angles which presents itself in the course of this investigation, and which may perhaps throw some light on the nature of an infinite angle, though it is not so readily susceptible of geometrical illustration as the case already considered. It has been observed that any angular position furnishes an infinite number of values of θ_n, and that the longitude has a corresponding number of values, connected by the equation

$$(l+2n\pi)\tan\theta_n=\log\cot\!\text{an}\,\frac{\mu}{2}.$$

By increasing n (which denotes the number of circuits which the course makes round the sphere) without limit, θ_n diminishes without limit; and the course approximates to an infinite number of circuits round the equator. The series of infinite longitudes now intended to be brought under consideration, consists of the limits of the values of the longitude traversed when θ_n approaches 0, for all positions on the sphere from the equator to the pole. When the point is at the pole, the infinite angle under consideration is that which we have already noticed as being of a very high order of magnitude; its value is infinite, not merely because $\tan\theta_n$ is zero, a circumstance which for our present purpose is common to all other positions, but also because $\log\cot\!\text{an}\,\frac{\mu}{2}$ being $\log\tan\frac{\pi}{2}$ is infinite. As the position descends from the pole towards the equator, the limit of the longitude traversed assumes still an infinite value, but diminishes in proportion to $\log\cot\!\text{an}\,\frac{\mu}{2}$, until the point falls upon the equator itself, in which case the value is a transitional phase of the series of infinite angles, and it assumes the form $0\div 0$, where the two elements of which the zeros are the limits are independent of each other; from which we are to infer, what is indeed geometrically evident, that the course consists of an arbitrary number of complete revolutions $2n\pi$, in addition to the original longitude of the point l. On the other side of the equator, the longitude traversed passes through an exactly similar series of values, but without any change of sign. We have thus another point of view from which we perceive that the limiting conception of a series of infinite angles of varying magnitudes proves to be an angle possessing an infinite number of values.

Having thus acquired some idea of the meaning of an infinite angle, by observing its demeanour through the various phases of the above geometrical illustrations, the next question which suggests itself is, how are we to deal with its trigonometrical functions. Confining ourselves to the set of angles which we have denoted by ∞_θ (the longitude traversed in reaching the pole at the angle θ), we may safely assert that these functions are independent of θ; for whatever may be the value of θ, all the values of ∞_θ corresponding to them are geometrically identical; and we are here dealing with purely geometrical functions. It follows that a trigonometrical function of an infinite

angle is the same function of that angle which has at once every possible value, or which is the same thing, every possible value within one complete period. We should therefore be inclined to say, that, speaking geometrically, $\cos \infty$ or $\sin \infty$ has no particular individual value, but that it possesses at once every value between -1 and $+1$, both inclusive. We shall not, I apprehend, arrive by any process of abstract reasoning at an analytical equivalent for these and similar expressions. We may, however, interpret them by reference to particular problems, the solution of which involves principles not purely algebraical; and the question will then arise, how far it is safe, having regard to the nature of these principles, to consider the interpretation as universal.

Suppose a point placed upon a sphere whose equator is horizontal, and such point descending by the force of gravity, and that a person is entitled to receive, (or obliged to pay, as the case may be,) such a fraction of a pound as is denoted by the cosine of the longitude of the place at which the point traverses the plane of the equator. For every position of the point up to, but exclusive of the pole, the value of this person's interest is simply the fraction $\cos \theta$ of a pound, θ being the longitude of the original position. If the point be actually on the pole, the problem considered as a physical one fails; and the answer assumes the form of a trigonometrical function of an angle which has no one value in particular more than another. If we bring this limiting case within the scope of the problem by proposing it in this form:—a material point rolls from the pole of a sphere to the equator down a meridian, determined by some impulse extraneous to the problem; what is the value of the interest of a person who is to receive, (or pay, if the result be negative,) the fraction of a pound above indicated?—the algebraical answer is the same as before, viz. the cosine of an angle which has any or every value, no one in particular more than another; but the problem is not now purely algebraic, but belongs to the Theory of Probabilities, which tells us that the answer is $\big(\cos n + \cos (2n) + \ldots + \cos (mn)\big) \div m$, where n diminishes without limit and $mn = 2\pi$, that is, $\int_0^{2\pi} \cos \theta \, d\theta$; and this, which is the mean of all the possible values of $\cos \theta$, is therefore, in this problem at least, the interpretation of the cosine of the indeterminate angle which denotes the longitude of the pole. Perhaps this doctrine of the interpretation of indeterminate values may be stated as follows:—If a problem when treated analytically give an indeterminate result of which all the individual values are calculable, and if the same problem when treated by the principles of the science to which it belongs give a specific result, we are warranted in saying that the latter is *quoad subjectam materiam* the interpretation of the former, and may be treated as its analytical equivalent; this doctrine being subject to the implied condition that the science to which the problem belongs, and which gives us the specific result, is a science whose fundamental principles do not rest on induction in any other sense than the axioms of algebra do.

A and B engage in a game in which they will win alternately, A winning first: what is the present value of A's ultimate winnings when they rise? The only answer given by algebra is $\frac{1-(-1)^x}{2}$, where x is the number of games about to be played; but the real answer is evidently $\frac{1}{2}$, so that $\frac{1}{2}$ ought to be the arithmetical interpretation of $\frac{1-(-1)^x}{2}$; or the equivalent of $(-1)^x$ is 0 if x be indeterminate and integer; and that of $(-1)^\infty$ is the same, provided the infinity used be the limit of the ordinal series 1, 2, 3, 4......, and not the limit of any partial series, as 1, 3, 5, 7.... or 2, 4, 6, 8.......

It would appear that problems of this sort are not soluble by algebra alone, when the problem itself contains an indeterminate element; but if it contain an infinite in lieu of an indeterminate element, it is soluble by algebra, as a limiting case of some more general problem. Suppose a person plays a succession of games, of which, when divided into sets of three, he wins in every first game a pounds, in every second b pounds, and loses in every third game $a+b$ pounds; what is the present value (apart from any considerations of time) of what he will gain, supposing that he plays until the happening of some event unconnected with the game and which may never happen? The answer given by the Theory of Probabilities is $\frac{1}{3}(2a+b)$, being the mean of the three possible results of one set of games. If the conclusion of the playing be indeterminate, algebra gives only an indeterminate result; but if the conclusion of the playing be indefinitely postponed, the answer to the problem is, the value to which the series $ax+bx^2+cx^3+ax^4+bx^5+cx^6+\ldots\ldots$ (c being $-(a+b)$) approximates as x approximates to unity; and this also is $\frac{1}{3}(2a+b)$. The problem is in fact brought within the domain of algebra by considering it as the limiting case of another problem, in which an algebraic relation exists between the values of the winnings of each game; and the value of the limit depends upon the nature of the connexion. In the problem proposed, the a pounds won in the first game has no kind of connexion with the a pounds won in the 4th, 7th, &c. games; but in the extended problem a connexion exists, inasmuch as we consider that when ax is the value of a pounds at the end of the first game, ax^4, ax^7... represent the values of a pounds at the end of the 4th, 7th, &c. games; and it is this consideration which renders the problem an algebraical one.

Considerations of this nature seem to tend to the conclusion, that we are not to expect from algebra alone, as that science is at present constituted, the discovery or proof of the principle that the analytical equivalent of an indeterminate expression is the arithmetical mean of all its values, or any principle of this character; for algebra being the science of symbols irrespective of their meanings, knows nothing of symbols which are of their own nature periodic or alternating, or otherwise limited as to the values they are capable of having, or of symbols which are indeterminate in point of value; except indeed when they occur as limiting cases of particular problems; in which cases their values are to be learnt from the specialties of the problem, or in other words, the science to which the data of the problem belong.

Returning to the consideration of infinite angles, it will be readily seen that ∞_θ and $\infty_{\pi-\theta}$ are identical in every particular except sign. Considering these angles as longitudes *attained*, they possess a species of identity which ∞_θ and $\infty_{\theta'}$ do not possess; the former pair have passed through precisely the same values, have traversed every meridian the same number of times; the latter pair have not. Viewing the two pairs of infinities as angles impressed with every value through which they have passed, now that they have arrived at an indifferent or neutral value, the former pair possess an absolute identity (except in sign) with reference to our mode of interpretation. If we take two infinities which differ otherwise than in sign, and if we permit ourselves to say that $(-1)^{\infty}=0$ and $(-1)^{\infty'}=0$, yet we could not thence infer that $(-1)^{\infty}=(-1)^{\infty'}$; but since $-1=-1^{-1}$ identically, we may be sure that $(-1)^{\infty_\theta}=(-1)^{\infty_{\pi-\theta}}$ since $\infty_\theta=-\infty_{\pi-\theta}$; and if these quantities are to be interpreted each into zero, we may be sure that it is the same zero. But whether it be, or be not, safe to affirm that $(-1)^{\infty}=0$ universally, we may certainly affirm, (the three infinities being the same,) that $\frac{(-1)^{\infty}}{(-1)^{\infty}+(-1)^{-}}=\frac{1}{2}$.

This consideration enables us to obtain the following results, without the application of the principle of mean values, which, however, gives the same results:—

Since $2\sin x = -\sqrt{-1}\left((-1)^{\frac{x}{\pi}} - (-1)^{-\frac{x}{\pi}}\right)$, we have $\sin \infty = 0$.

Since $\tan x = -\sqrt{-1}\,\dfrac{(-1)^{\frac{x}{\pi}} - (-1)^{-\frac{x}{\pi}}}{(-1)^{\frac{x}{\pi}} + (-1)^{-\frac{x}{\pi}}}$, we have $\tan \infty = -\sqrt{-1}(\frac{1}{2} - \frac{1}{2}) = 0$;

and generally, the odd functions and their odd powers will be found to be zero. The value of the even functions is not immediately perceived, unless we conceive ourselves at liberty to assume that $(-1)^{\frac{x}{\pi}}$ and $(-1)^{-\frac{x}{\pi}}$ become 0 when x is infinite. If, however, we bear in mind, that in speaking of ∞ as an angle, we are using the symbol in its ordinary algebraical sense of a number which is larger than any number we can name, and which does not admit of alteration by the mere addition or subtraction of any finite quantity, and concerning whose value nothing further can be predicated, we shall easily perceive that $\cos \infty$ must have the same value as $\sin \infty$; for since

$$\cos x = \sin\left(x + \frac{\pi}{2}\right) = -\sin\left(x - \frac{\pi}{2}\right)$$

we have, with the above meaning of infinity,

$$\cos \infty = \pm \sin \infty, \text{ and therefore } = 0;$$

from which we are to infer that $(-1)^{\infty}$ and $(-1)^{-\infty}$, or $\epsilon^{\pm\infty\sqrt{-1}}$, are both zero, since they are equal and their sum is zero.

Since $\tan x = \dfrac{\sin x}{\cos x} = \dfrac{0}{0}$ when x is $\infty = \dfrac{\cos x}{-\sin x}$, we have $\tan \infty = -\dfrac{1}{\tan \infty}$.

By taking the powers of $2\cos x = (-1)^{\frac{x}{\pi}} + (-1)^{-\frac{x}{\pi}}$,

and of $$2\sin x = -\sqrt{-1}\left((-1)^{\frac{x}{\pi}} - (-1)^{-\frac{x}{\pi}}\right),$$

and observing that $(-1)^{\frac{x}{\pi}}$ and $(-1)^{-\frac{x}{\pi}}$ are both zero when $x = \infty$, we obtain

$$\cos^{2n}\infty = \frac{1}{2^{2n}} \cdot \frac{2n(2n-1)(2n-2)\ldots(n+1)}{1.2.3\ldots.n};$$

$$\cos^{2n+1}\infty = 0;$$

and the powers of the sines are the same. The assertion that $\tan \infty = 0$ is at variance with the result given by Professor De Morgan in his treatise on divergent series in the Cambridge Phil. Trans. (vol. viii. part 2). The result deduced in that paper by two methods is $\tan \infty = \pm\sqrt{-1}$. The first method depends on the assertion that $\log\left(\dfrac{a}{-a}\right) = \pi\sqrt{-1}$, and $\log\left(\dfrac{-a}{a}\right) = \pi\sqrt{-1}$; but inasmuch as the two fractions whose logarithms are required are, from their derivation, reciprocals of each other, I apprehend that the sum of their logarithms is simply the logarithm of 1, or zero; which would lead to $\tan \infty = 0$. The second method leads to the equation above deduced, $\tan \infty = -\dfrac{1}{\tan \infty}$, from which however we are not at liberty to deduce $\tan \infty = \pm\sqrt{-1}$. Independently of the *à priori* difficulty of believing that the mean value of an odd function can be other than zero, I conceive that any

process of mean values giving an ambiguous result, such as $\pm\sqrt{-1}$, would imply that the real result is the mean between the two values of the ambiguous expression, which in the present case would be zero. That

$$(\tan 0+\tan n+\tan n+\tan(2n)+\ldots.+\tan(mn))\div m,$$

where $mn=2\pi$, approximates without limit to zero as n diminishes without limit, may be shown by causing n to diminish in such a manner as never to be an aliquot part of $\frac{\pi}{2}$ or $\frac{3\pi}{2}$. This may be effected by making n an odd aliquot part (as small as we please) of π. It is then certain that the terms of the above series cancel each other, and we are not embarrassed with the difficulty of proving that $\tan\frac{\pi}{2}+\tan\frac{3\pi}{2}=0$; for we never fall on these values. Moreover, it has already appeared that the angle whose tangent is $\sqrt{-1}$ is $\infty\sqrt{-1}$; which corresponds with the value derived from the expansion of $\tan^{-1}x$ when x is made equal to $\sqrt{-1}$; while the equation $\tan^{-1}\sqrt{-1}=\infty$ would be at variance with this expression.

In conjunction with $\tan(\infty\sqrt{-1})=\sqrt{-1}$ it may be useful to notice,

$$\cos(x\sqrt{-1})=\frac{1}{2}(\epsilon^{x}+\epsilon^{-x});\ \cos(\infty\sqrt{-1})=\infty;$$

$$\sin(x\sqrt{-1})=\frac{\sqrt{-1}}{2}(\epsilon^{x}-\epsilon^{-x});\ \sin(\infty\sqrt{-1})=\infty\sqrt{-1};$$

and to compare these expressions with the hyperbolic tangent, cosine, and sine of a real angle which are respectively 1, ∞, and ∞.

We have already remarked that the results here contemplated, whether arrived at by the principle of means, or by reference to the problems producing them, are to be regarded not as unique values, but as interpretations *quoad* the particular subject in hand. It is not true that $1-1+1-1+\ldots..$ equals $\frac{1}{2}$ generally, or that this series has any unique value; for it may be made to represent any proper fraction $\frac{m}{n}$ by making it the limit of the series

$$1-x^{m}+x^{n}-x^{m+n}+x^{2n}-x^{m+2n}+x^{3n}-x^{m+3n}+\ldots..\text{ or }\frac{1-x^{m}}{1-x^{n}}.$$

If A and B play, and win alternately, A winning the first, the value of A's winnings is $\frac{1}{2}$; but that is only on the assumption that there are no drawn games; for if there be $m-1$ drawn games after each game won by B before A wins again, the value of A's winnings is $\frac{m}{n}$, being the limit of the above series; and if the number of games played be indefinite, the doctrine of means leads to this identical result.

It has been suggested by Mr. De Morgan in the memoir above referred to, that the fabric of periodic series and integrals raised by Fourier, Poisson, Cauchy and others would be exposed to great danger by the production of any case in which $1-1+\ldots.$ should differ from $\frac{1}{2}$ when it is the limit of a series $A_0-A_1+\ldots..$ If this suggestion should prove to be well-founded, it would lead to great doubt as to the truth of the results obtained by these analysts; for although I am not able to adduce any instance in which the known analytical envelopment of such a series as $x^{\phi(0)}-x^{\phi(1)}+x^{\phi(2)}-x^{\phi(3)}+\ldots$ differs from $\frac{1}{2}$ when $x=1$, yet it is easy to adduce cases in which the doctrine of mean values applied to such a series fails to produce $\frac{1}{2}$ as the limiting value. This doctrine gives as the limiting value,

$$=\frac{\phi(0)-\phi(1)+\phi(2)-\phi(3)+\dots\dots\pm\phi(n)}{\phi(n)},$$

n being made infinite. If $\phi(n)$ be n^2, so that the series becomes $1-x+x^4-x^9+x^{16}-\dots\dots$, this mean value is $\left(1+5+9+13+17+.+(4p+1)\right)\div(2p+1)^2$, which, as p increases, approaches $\frac{1}{2}$; and in this case the analytical envelopment, which can be found in the shape of a definite integral, also gives $\frac{1}{2}$. The doctrine of means gives the same result for any other integer power of n; and probably, if the analytical envelopment were found, it would give the same value. But if $\phi(n)$ be of the form a^n, the doctrine of mean values gives as the limit of the series

$$x-x^{(a)}+x^{(a^2)}-x^{(a^3)}+x^{(a^4)}-\dots\dots,$$

not $\frac{1}{2}$, but $\dfrac{1}{1+\frac{1}{a}}$; and this circumstance of itself would induce me to require to see the analytical envelopment of the series before I pronounced its limiting value to be $\frac{1}{2}$. There are algebraic considerations which would rather tend towards the conclusion that this limit is a function of a; for when a is 1, its value is $\frac{1}{2}$; and if a be infinite, its value appears to approximate to unity. It is perilous, however, to hazard surmises as to the value of this limit, so long as no finite equivalent for the series is produced.

Report on the Improvement of Telescope and Equatorial Mountings. *By* Thomas Grubb, *M.R.I.A.* &c.

The labours of the Earl of Rosse, now only perhaps receiving due appreciation, have placed beyond doubt the practicability of producing specula for reflecting telescopes of dimensions equalling, if not exceeding, those which the conditions of our atmosphere permit of being used with advantage, combined with an accuracy of surface and consequent excellence of definition which we can scarcely either hope or desire to surpass.

Meantime the achromatic objective has received but small increment of dimension, and is now probably for ever distanced, in this respect, by its competitor the reflector. The spirited exertions of the Messrs. Chance of Birmingham have indeed produced a pair of discs suited to the formation of an object-glass of about 29 inches diameter, but these exertions have not been seconded by a corresponding spirit in Great Britain, either public or private. A few years since, the possible acquisition of an achromatic telescope, of corresponding gigantic size, was looked forward to as a national triumph, if ever accomplished; but our Government, retaining its character of proverbial supineness (if not apathy) in such matters, has allowed these splendid discs to be transmitted to a more congenial kingdom; yet even there the work seems to progress but slowly, and I apprehend that their formation into an object-glass is still a work for the future. Four years have now passed since the production of these discs, and nearly three years since, on being applied to by Messrs. Chance, I offered to form them into an object-glass. Under such circumstances it is desirable that attention should be turned to the reflecting form of telescopes as that alone suited for instruments of the largest dimensions, and important that these should receive from time to time such accessions of improvement as the progressive steps in arts or science place at our disposal.

Now the two points in which inferiority may be at present held as against the reflector are—the greater liability of the surfaces to tarnish, and the less intrinsic brilliancy of the pencil. In respect of the first, I hold the objection to be much less in amount, with good specula, than usually supposed. If we have to infer that Sir J. Herschel frequently repolished his mirrors at the Cape, we know that some specimens of optical glass have rapidly deteriorated. It was stated by Professor Moll, of Utrecht, at the former Meeting of the British Association in Dublin, that there was then in Paris an object-glass through which we might in vain attempt to look; but it is manifest that neither a low quality of speculum metal, nor glass carrying its own destruction within its substance is fitted for optical instruments, and that both should be equally avoided. As a proof of the permanence of good specula metal, I may mention that on a recent occasion, a surface twelve years polished showed an increase of only six per cent. of reflecting power on being repolished.

In respect of the second point of inferiority of the reflector, viz. the greater absorption of the incident light, and consequent lesser intrinsic brightness of its pencil, as compared with that of the achromatic. I would observe, *in limine*, that this difference decreases as the size of the object-glass increases, so that an object-glass of 4 feet diameter, and of a thickness adequate to resist flexure, would transmit little, if any, more light to the eye than a reflector of equal aperture as it is now possible to construct it. Such considerations do not however lessen the importance of obtaining for the reflecting telescope every possible accession as well to the permanence as to the reflective power of its surfaces, *compatible* with their general accuracy and perfection of figure. To the improvement of the reflecting telescope in these respects, I have lately devoted some attention; how far I have realized what is valuable remains to be shown.

So far as the Cassegrain and Gregorian forms are concerned, these improvements are based upon the employment of one or more silvered (not quicksilvered) surfaces; and my first application of it has been to that form of the reflecting instrument which I have long preferred (not perhaps without good reason) to all others, viz. the "Cassegrain." Convinced, from previous practical working of both speculum metal and glass, that both were capable of receiving equal degrees of accuracy of surface, I conceived it unnecessary to stop to consider whether the failure of a recorded attempt to construct a reflecting telescope of quicksilvered surfaces was due to the errors of workmanship of the artist, or the formula by which he was guided, and selected the small mirror of the Cassegrain telescope for experiment.

Now the most obvious construction for a silvered mirror for such, was to form a lens (so to speak) of equal thickness throughout, having no dispersion, and therefore requiring no correction of colour, and to silver the concave surface. This construction I rejected, notwithstanding its simplicity, on considering that there would be a secondary image (coinciding nearly with the primary) formed by the outer or unsilvered surface, and producing what is called a "ghost" in the field of view.

I therefore assumed a radius of curvature for the outer surface differing considerably from that of the inner or silvered surface; and as this would produce refraction and therewith colour, it became necessary to adopt an achromatized compound of crown and flint glass. This being constructed, has proved altogether satisfactory: the inner surfaces being cemented, no appreciable loss of light occurs from using two lenses instead of one; the reflecting surface being as yet only quicksilvered, no increase of light should be expected: still, when the combination is used in a telescope, the image

appears both brighter and whiter than when using the ordinary small speculum; the image also appears perfectly free from chromatic dispersion. When the quicksilver shall have been replaced by a surface of pure silver, the increase of light will of course be equivalent to the proportionably higher reflective power of the latter, which, in the absence of good photometric observations, may be estimated at the least at a fourth. The same principles I propose to apply to the improvement of the Gregorian telescope, with inverted surfaces.

In the case of the Newtonian reflector, and where the aperture does not exceed 12 inches, the prism of total reflexion with plane surfaces, as at present occasionally used, seems hardly to admit of improvement; but for much larger apertures, and especially when we approach the size of Lord Rosse's great telescope, where the requisite size of the prism would involve the passing of the rays through about 6 inches of glass, the case is widely different, and if the difficulty, not to speak of the expense, of procuring prisms of homogeneous and perfectly annealed glass of adequate dimensions did not prevent their use, their thickness would go far to neutralize their usefulness.

The arrangement which here first presented itself, as affording some special advantages and permitting of a great reduction in the size of the reflecting prism, was to construct the prism with a converging power, and place it beyond the focus of the large speculum, so that the reflected pencil would form a secondary image to be viewed by the eye-glass instead of the primary. By adopting an aplanatic construction for the prism, the distinctness would be preserved, and the entire arrangement better (as having fewer surfaces) than the more obvious one of a small plane prism placed a short distance within the focus, and reaching (so to speak) this image with a long compound eyepiece of four lenses. Both constructions, however, include two obvious disadvantages; viz. a secondary image, illuminating the surfaces and making the field less dark than otherwise; and secondly, and which is of more consequence, a very reduced field of view.

That form of the reflecting prism which I propose for adoption in the case of large Newtonian reflectors, is as follows:—the prism is an aplanatic compound of *negative or diverging* power; this power is of course arbitrary or *ad libitum*, but I prefer that it be such as will about halve the angle of convergence of the pencil passing through it from the large speculum. Assuming this proportion to be adopted, the practical effect will be as follows:—the requisite size of the prism will be just halved (linearly), the resulting image will be doubled in linear dimensions, and the magnifying power (with any given eyepiece) augmented in the same proportion. The length of the telescope will indeed be increased, but only by one-fourth of a diameter of the large speculum. This arrangement has the obvious advantages of the fewest possible surfaces, and no secondary image. It has been objected that the field of view is by it lessened. I cannot consider such to be the case in a practical sense; for even with Lord Rosse's telescope of 54 feet focus, the lowest eyepiece in general use may be doubled in all its proportions, and with such lower-power eyepiece and the proposed prism, the magnifying power and angular extent of field would correspond with these same as obtainable from the combination of the higher eyepiece and ordinary plane mirror or plane prism.

It will be observed that my proposed improvements, so far as described, relate only to substitutes for the *small* mirror of reflecting telescopes; and for so far I consider they may be confidently and advantageously applied. I see, however, no reason why the same may not be applied to the large specula

of the smaller reflecting instruments, and, assuming that either the Cassegrain or Gregorian form is selected, a beautiful principle of correction is indicated, viz.: let both large and small mirrors be made each of a single piece of glass, let the outer surface of the larger lens (that which when silvered becomes the larger speculum of the telescope) differ in its radius of curvature from that of the silvered surface by the least quantity which will sufficiently dissipate its reflected image in the field, and let the outer surface of the smaller lens (that which when silvered becomes the small speculum) differ from the silvered surface of the same in an opposite manner, *i.e.* (allowing for the distance between the two lenses) so that the colour produced by the refraction of the larger lens shall be balanced by the colour of an opposing refraction in the smaller. This done, the combination as a whole will be achromatized, and the secondary images (or "ghosts") so far dilated as to be insensible in the field.

For the great speculum of instruments of the largest class we probably must retain the speculum metal; there is, however, a construction which is possibly practical up to a considerable size, viz. that of a comparatively thin lens, silvered at the back, and supported throughout its back (or nearly so) by a thick or ribbed disc or casting of glass or metal, ground to fit with adequate accuracy.

It may be useful, in concluding this section of the subject, to make a rough comparison of the achromatic and reflector. A 15-inch reflector, in which the suggested improvements were carried out so far only as the small metal is concerned, would equal a 12-inch achromatic in light, and a reflector of 36 inches in diameter, similarly circumstanced, would be more than equivalent to an achromatic of the size of the 29-inch discs already spoken of, while, the length of the telescope being in each instance, for the achromatic, more than double that of the reflector, the expense of the mounting may be estimated as fourfold.

In passing to the second division of my subject, viz. the improvement of the equatorial mounting of large telescopes, I would first briefly advert to the several constructions in use, and which may be classed under three varieties, two of which are of English, the third of German origin. We have, then, the long-polar axis variety, which has the great disadvantage of the unsteadiness resulting from the telescope being attached to nearly *the weakest part of an axis longer than itself*. Secondly, we have the overhanging construction, consisting of a cone of great comparative weight and dimensions, and prolonged beyond its upper bearing in a biforked manner, thereby admitting of the telescope turning on bearings within the projecting fork. This construction requires for steadiness an unwieldy mass of moving matter in proportion to the optical power it supports, four tons being used in the case of a telescope of 8 inches aperture, a mass tenfold that required with a better construction.

The third variety, or German form of equatorial, has the advantage of the telescope being supported as close as possible to the strongest part of its polar axis; and the efficiency of such mounting is placed beyond doubt by the well known Dorpat instrument, and subsequently by the working of still larger instruments, for example, that erected many years since in this country for E. J. Cooper, Esq., where the telescope is $13\frac{3}{10}$ inches aperture and $24\frac{1}{2}$ feet focus, and which has remained in effective use, with scarcely any repair, from the time of its erection, although unprovided with a dome or other roof,—a point of no slight importance when we consider the expense of such for so large an instrument, not to speak of the labour and time consumed in moving it during observation.

It will be seen, from this short mention of the several varieties of equatorial mountings, that I give a most decided preference to the general form or principles of construction of the German instrument, in which preference it cannot be supposed that there is any undue element of partiality, as none of the forms are of my own devising. The British Association, it will be recollected, long since impressed with the importance to science of having a powerful instrument sent to a southern latitude, urged the British Government to contribute to the work, and appointed a committee to examine and select the most effective form of instrument, &c. &c. Anxious to be a successful competitor in such an undertaking, I applied myself to remove the only apparent objection to the German form of instrument, and also to devise such modification of its details as would suit it pre-eminently for a *large reflecting telescope.* Both these objects were accomplished with entire success. My plan, as also estimates, had the honour of being approved of by the Committee before referred to; and although it would now appear as if, from some occult cause, the distinction of being the constructor of the proposed instrument is likely to remain *an honorary one*, still, as the improvements spoken of are applicable to instruments of much smaller dimensions, it may not be unprofitable to lay the general principles and results of these before the Association.

That which the German form of equatorial seemed alone to require, was a system of equipoise *inter se*, unobjectionable in itself, and which would reduce the nature of the pressures of the declination axis on its bearings to the same which these would be if the polar axis were *vertical* instead of inclined to the co-latitude of the observatory. The declination axis of a large instrument of the German type has necessarily great diameter, and its bearings, if ground in to fit without shake, as they may be in a small instrument, would have too much friction; it is therefore desirable that the bearings should be in effect Y*s*, and in order that such bearings shall be as admissible as in a meridional instrument, the pressure of the axis on each side of its Y bearing should be *equal in every position of the instrument*; moreover, it is desirable that the end pressure of the declination axis, in all positions of the instrument out of the meridian, shall be neutralized. These important conditions are perfectly fulfilled by a system of internal counterpoise, which, being applied, *then* permits of an external system of anti-friction rollers, relieving the Y bearings of all but a fractional portion of the remaining pressure of the declination axis and its appendages (viz. the telescope and its counterpoise). The result of such arrangement may be readily anticipated; an achromatic telescope of 12 inches aperture and 20 feet focus, so mounted and with perfect steadiness, is moved by a force of about one pound applied at the eye end.

Secondly, and for the equatorial mounting of the largest reflecting instruments up to 6 feet diameter (the size of Lord Rosse's), if required, I modify the German type, as shown in the drawings exhibited, by placing the declination axis within instead of beyond the larger end of the polar, and I invert the whole. Thus the previous steadiness is rather increased; the bearings of the polar axis may both be of minimum size, and the centre of gravity of the whole instrument is brought as close to the ground-level as can be desired, instead of being considerably aloft; also, the settings and readings of the largest instrument are rendered most convenient, and the observer is generally close to the ground, and never more than a few feet from it.

The subjoined Table contrasts the weights to be moved and power required for the same, in the *second English* and *improved German* forms of equatorials, for telescopes of several sizes, viz.—

	A	B	C	D
No.	Size of Instrument.	Forms of Mounting.	Weight to be moved, in lbs.	Force required, acting at a radius of 5 feet.
1.	For a 4-feet reflector....	English form No. 2.......	45,000	250
2.		German form improved.	19,000	20
3.	For an 8-inch refractor..	English form No. 2.......	8,000	45
4.		German form improved.	600	1
5.	For a 12-inch refractor..	English form No. 2.......	16,000	90
6.		German form improved.	1,200	2

In respect to the foregoing Table, it is right to state, that, so far as Nos. 1 and 2 are concerned, the data in columns C and D are the results of calculation; and the same is to be understood of column D in the case of No. 3. The data for No. 5 are taken directly from those of No. 3, while the numbers appended to No. 6 give the result of actual experience.

Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester. By James Buckman, *F.L.S., F.A.S., F.G.S., &c., Professor of Geology and Botany, Lecturer on Geology, &c. at the Cheltenham Proprietary College.*

The experimental plots in the garden of the Royal Agricultural College rest partly on a thin bed of forest marble clay and partly on the brashy soil of the underlying Great Oolite, so that, although most of the soil is of a heavy tenacious character, still a large portion is that of the porous Stone-brashes so prevalent in the district, the nature of the geology being readily made out from the following section.

a. Forest Marble Clay. *b.* White Freestones of the Great Oolite.

Neither the staple of the land itself, nor any method of cultivation that has as yet been adopted renders this part of the Royal Agricultural College Farm better, if indeed equal, to the land of the best part of the farm; so that the agricultural experiments at least are not likely to suffer in value from being carried on too exclusively under the conditions of garden culture.

The garden is for the most part divided into plots, the greater portion of which are $2\frac{1}{2}$ yards square—many however are double that size,—whilst small borders are occupied with single specimens of flowering plants, the latter being mostly grown for assisting demonstrations in the lecture room.

With merely agricultural experiments, the method I have adopted is to first use a small plot, and then adopt either a 5-yard plot or four of these united, after which the matter is transferred to the farm; so that as time progresses, and facilities for carrying on these experiments increase, it is hoped that this garden may be the means of introducing new and valuable varieties of crops to the farmer, as well as of elucidating some interesting facts and principles in Botanical science.

The plots for the present year, 1857, are employed in the growth of plants in the following groups:—

	Plots.
1. Meadow and pasture grasses	66
2. Cereal grasses—Corn crops	16
3. Papilionaceous plants	30
4. Green feeding crops	20
5. Esculent vegetables	9
6. Economic and medicinal plants	16
7. Weeds	5
8. Flowering, ornamental, and other plants	50
Total	212

1. The Grasses.—These may be very conveniently divided into the following groups.

a. Grasses of value in meadow and pasture.

b. Grasses which are but pasture or agrarian weeds.

c. Grasses which indicate certain conditions of soil, climate, &c.

As regards the plots of grasses generally, I may state that last year these consisted to a great extent of two sets, one planted five years before, and a new lot now just coming to perfection, the difficulty of keeping species unmixed, and other circumstances attendant upon growing specimens in small plots, rendering frequent renewal absolutely necessary. As respects the purity of a crop, the older beds offered some most interesting observations, as they show how in a short period one species may be entirely lost, and the ground be taken possession of by others; hence the following:—

Original Crop*.	Possessed by
Phleum pratense.	Arrhenatherum avenaceum.
Alopecurus pratensis.	Dactylis glomerata.
Lolium Italicum	Poa pratensis.
——— perenne.	Poa pratensis and others.
Cynosurus cristatus.	Holcus lanatus.
Poa trivialis.	Poa nemoralis.

Three beds, side by side, have become mixed in the following manner.

1.	2.		3.
Triticum caninum.	Wheat 1.	Last year.	*Hordeum murinum.*

Observations of this nature are interesting in a practical point of view, as, from cultivation or the want of it, meadows are constantly changing their contents, good grasses gaining the ascendant in the former, and bad in the latter. In my plots, bad grasses, that is those of a poor feeding quality, take possession of plots originally sown with better kinds; this arises from the circumstance of the general poverty of the soil, which is assisted by these crops never being depastured like those of meadows, but on the contrary are left to perfect themselves for the teaching of the students, and consequently are annually cut down as ripened or seeded grasses, thus affording a practical example of the injury arising from exhausting crops, besides showing that

* These and most of the older beds have this year been occupied by totally different crops, the old crops of grasses being gradually destroyed.

many of the grasses only maintain a perfectly perennial habit by being cropped off before they have seeded. This consummation having been attained, many species, such as the *Loliums*, *Hordeums*, *Dactylis*, and *Alopecurus*, die out the same, or at best the second year afterwards; and indeed in cultivation, even when cut before it is ripe, the old plants gradually die out.

Grasses indeed differ so much in the species that prevail and the well or ill doing of these according to circumstances, that the practical observer of them, either in a wild or cultivated shape, or, better, both, may become acquainted not only with the broad features connected with the conditions of soil, but all their inflections, such as its value, the cultivation it has experienced or that should be adopted, mechanical texture, want of draining, and the like.

As regards particular Botanical facts that have received illustration from my experiments, I would shortly comment upon the following genera:—*Alopecurus*, *Dactylis*, *Agrostis*, *Poa*, *Festuca* and *Bromus**. Of the first two genera, I received packets of seed from the seedsman with the following names:—

Alopecurus pratensis.	*Dactylis glomerata.*
„ *nigricans.*	„ *gigantea.*

The *A. nigricans* I take to be but a variety of *A. pratensis*; and indeed, after three years of growth, it may almost be pronounced as identical. Both do well; and I can see no reason for preferring the one to the other, so alike are they in growth and habit.

As regards the two names of *Dactylis*, for they are nothing more, they are here inserted to note with reprehension a practice too often adopted by seedsmen, of giving a new name from some accidental enlargement of form perhaps arising from suitable soil—or other unimportant distinctions; and thus disappointment results to the cultivator, while works are burdened with synonyms.

Agrostis.—The last year's plots of this were as under:—

Plot A. *Agrostis vulgaris.* Plot B. *Agrostis stolonifera.*

These were sown in 1855, and at the last meeting they presented the following appearances:—

A. "Presents the usual delicate *A. vulgaris* of the grass meadows with a few plants of *A. stolonifera* intermixed."

B. "The general plant is *A. vulgaris* having a *few A. stolonifera* intermixed; and these latter present more of the *A. alba* form than of the congested inflorescence and true stolon growth of the *A. stolonifera.*"

This seems to favour the view that the three forms are all referable to a single species†, as when cultivated in a like position their broader features of distinction are lost, and the seed of one, though for the most part coming true, will still send up exceptional examples of each of the others; but the diversity of conditions under which the three forms occur in nature seems sufficient to account for the different aspect which they assume, such as—

A. vulgaris, common to upland meadows.

A. alba, in ditches and damp places.

A. stolonifera, in stony brashes, mostly an accompaniment of agrarian conditions.

* Avena and Ægilops to be noticed in the Cereal list.

† This is more strongly confirmed in the present year, 1857, as now
Plot A is attaining the size and appearance of *A. alba*.
Plot B is nearly all *A. alba*. These plots are on a thin clay bed.

Poa.—Of this genus, among other species the two following were sown side by side.

P. aquatica (*Glyceria*). *P. fluitans* (*Glyceria*).

These were sown in the autumn of 1855. During 1856 stiff and sturdy short-and rigid-leaved plants were forming; these leaves were so harsh as to cut the flesh on the slightest touch. During the present year, 1857, they have flowered, and to my utter astonishment the plants of both plots are the same; the culms were as much as a yard in height, and the flowers so small and ovate as quite to justify the retaining of the generic name of *Poa* for the whole group.

While these grasses were flowering, I watched them from day to day with great interest, as in all their parts they differed so much from any known species; the short rigid leaves with the angular sheath, and the elegant panicle of flowers from their size, and the rigidity of the whole plant removed these far from the *P. pratensis*, and the whole details differed so much from the forms whose seed was sown as well as from all other recognised forms, that while it showed me I could not have mistaken my seed, it also was convincing that I had obtained a new and singular variety. This indeed is not to be wondered at when we consider that both the forms, the *aquatica* and *fluitans*, absolutely grow in the water; but here I had got them to grow in an upland situation, and to manage like other upland grasses with only water from rain. Still the change was so curious, that I was anxious to re-examine the seeds as sown; and fortunately some of the packets were saved, and I can pronounce them true as named*.

Here then I cannot help concluding that even such dissimilar grasses as the typical forms of *P. aquatica* and *P. fluitans* are not specifically distinct; and though the former in its wild state bears a large and diffuse panicle of flowers, and the latter is almost as spicate as a *Lolium*, yet we may, I think, connect the evidence here presented to us with that obtained in the growth of the *Festuca loliacea pratensis* and *elatior* presently to be detailed.

However, I shall not conclude my experiments upon this subject without sowing some new plots with seeds of the hitherto supposed species gathered by myself for the express purpose; not that I in the least doubt these experiments, but in order, if possible, to note the changes more clearly†.

Festuca.—The species to be communicated upon I shall divide into two groups.

a. Festuca ovina.	*b. Festuca loliacea.*
„ *β duriuscula.*	„ *β pratensis.*
„ *γ rubra.*	„ *γ elatior.*
„ *δ tenuifolia.*	

a. These were sown six years since in three distinct plots, and they soon established themselves in a separate tufted method of growth. The first two years they were readily distinguishable; now, however, the following facts are observable.

F. ovina is about eighteen inches high; *F. tenuifolia, duriuscula* and *rubra* differ but slightly in size, and scarcely in details, and the creeping habit of root of the latter is entirely lost‡.

It may be remarked that the *F. rubra* is not amongst our wild forms at Cirencester, but I have occasionally met with specimens of *F. duriuscala* in

* The two packets were sent for examination.

† Specimens of the new Poas are sent for examination.

‡ Certainly not so much as regards the width and length of the leaves, as the same form takes on in bushes when compared with the open ground.

the road dirt with which the tops of our stone walls are frequently capped, having a decidedly creeping habit which, if shown as a tendency "in light sandy pastures near the sea" which is given by Hooker as the habitat of the *F. rubra*, may account for the difference.

As respects the varieties *F. ovina*, *tenuifolia* and *duriuscula*, it may be remarked that poor uplands present the first, the bushes and hedgerows around these the second, and meadows examples of the latter; but seldom are they greatly intermixed, which, perhaps, may be taken as an argument that these forms are but varieties induced by different circumstances. From long observation and experiment I can only so consider them; and had I a choice of names for the typical form, I should choose that of *duriuscula*, as the departure seems to be from that type, of which *F. ovina* is a mountain form, and *F. rubra* a seaside or arenaceous one.

b. Festuca loliacea varieties.

Six years since, I sowed the seeds of the three forms as below, and in the following order.

Festuca loliacea.	*Festuca pratensis.*	*Festuca elatior.*
1.	2.	3.

These plots the first year of flowering presented appearances as under:—

1st. *Festuca loliacea.*—Most of the plants of the true spicate type, but sparingly mixed with paniculate flowers: the herbage of which was of the rich green which characterizes *F. loliacea.*

2nd. *Festuca pratensis.*—All true, but with a tendency to a rigidity of leafage.

3rd. *Festuca elatior*, scarcely distinguishable from (2).

In three years great changes had been wrought as under:—

1st. *F. loliacea.*—No spicate flowers.

2nd. *F. pratensis.*—More rigid and larger, in fact none of the true meadow type.

3rd. *F. elatior.*—A little larger, but otherwise not distinguishable from (2).

In the fifth year the *F. elatior* prevailed in all the beds.

These plots are destroyed, as in 1855 the same experiments were recommenced in another part of the garden, the plots, however, being placed at a distance apart; and the present year they were plainly observed to be taking the same course as the others.

Here then, I think it satisfactorily proved by experiment that these three forms are all of them referable to a single species, as the changes indicated have taken place in individuals; they, however, maintain their distinctive characters under the following circumstances.

In meadows by the sides of rivers subject to occasional floods, as the Isis at Oxford, or irrigated meadows, as on the banks of the Churn at Cirencester, *F. loliacea* is constant in its characters, and is a most valuable grass for hay or pasture.

In rich meadow flats, as in the Vale of Berkeley—the celebrated country of the "double Gloucester cheese,"—the *F. pratensis* is a common and valuable denizen, and any meadow where it maintains its character may be considered as of good quality.

On the alluvial sandy clay banks by the seaside, or poor siliceous clays inland, the *F. elatior* rears its tall coarse form. In Gloucestershire the banks of alluvial mud thrown up to prevent the encroachments of the water in the Severn estuary are always occupied by this grass, which I look upon only as the extension of the *pratensis* from the rich flats within this boundary.

The *F. pratensis* is a grass which is usually recommended for admixture in forming new pastures, on which account there can be but little doubt that it was used in the glades laid down within the last few years at the entrance of Oakley Park, the seat of the Earl Bathurst. When first sown it came up true enough, though with a disposition to reediness; the last four years it has become wholly *F. elatior* in all its features, and is now in such large coarse "hassocks" as to be dissightly as a lawn, and much impairs the hay or pasture. The secret of all this appears to be that here it was sown on the forest marble sandy clays, the texture of which as a soil is similar to that in the favourite habitat of this form of grass, and this too, though in a less degree, no doubt, favoured the changes as observed in my botanical garden.

Here then we see, in these forms of Fescue, plants which assume what have been taken as specific characters, not only from change of circumstances giving rise to varieties which have been obtained from different generations by seeding, but these have assumed the form of *varieties* from the same seed and plants, and absolutely becoming *F. pratensis*, and afterwards *F. elatior* from the typical *F. loliacea*: and so certain is this in my experimental garden, that the result of twice sowing these three forms from seed from different seedsmen has been the permanent establishment of *F. elatior* in all three plots.

Bromus mollis varieties.

My experiments and observations upon the annual forms of Brome, though still in progress, yet seem to warrant a diminution in specific names; for example, *B. mollis* and *B. racemosus* of authors are sure to be intermixed to a greater or less extent from the same seed; thus the seed of the *B. mollis* will have a sprinkling of the *racemosus*, whilst seed of the latter will present exceptional examples of the former; and, besides, all distinction is lost in every shade of intermediate form by which the hairy and smooth varieties are connected.

Again, as regards *B. commutatus*, this is by far too common a grass in pastures subject to floods and in irrigated meadows, in which situation the *B. mollis* is quite exceptional. Now, as I have watched the laying out of poor pastures as irrigated meadows, I have always observed that two or three years is often sufficient to change the *B. mollis* which was alone before into *B commutatus*. Of course it may be considered that this was in virtue of that law of substitution of one species for another which so universally occurs on a change of soil and other conditions; but I incline to the belief that much of this is after all due to a change of form and specific character, and as regards the grass under consideration our chain of evidence is nearly complete when it is stated that the *B. commutatus* from the irrigated meadows, most certainly in experiments in my garden, has resulted in fine examples of *B. secalinus*, a form not before known there, and therefore not liable to have led me into error, as would be the case where the different varieties are wild natives near the spot.

I have not been able to experiment upon the whole of the forms of what I would term the *B. mollis* group, but I suspect that the *B. arvensis* which I this year found so abundantly on the chalk about Avebury, in Wiltshire, is but a form of the same; and though in all probability a foreign one introduced with "seeds," yet its individuality may have been implanted by

growth in a foreign soil, as I observed when in America most of the naturalized British plants had, to say the least, a different expression from the same grown at home.

2. Cereal Grasses—Corn Crops.—The experiments in this list to which I would direct attention are as under:—

	Plots.
a. Peruvian Barley succeeding Swede Turnips—manured with different manures	6
b. Sowing of wheat at different depths	2
c. Transmutation of oats	5
d. Experiments with Ægilops	3

a. The Peruvian Barley was sown on account of the interest of this variety, and also to occupy six large plots which were last year planted with Swede Turnips: five plots with different manures, and one without manure for comparison. The whole of the Turnip experiments, when complete, will form a substantive report, I hope, next year. It may be enough here to state that the result in the Turnips was widely different, but I could trace no difference in the Barley.

b. For two autumns past I have sown wheat at different depths, from one to seven inches. My crop of 1856 came up tolerably regular, and that from two to four inches in depth was certainly the best, the deeper sown being thin, and tillering but indifferently: this year, however, the deeper sown is very thin, and consequently with fine large ears, whilst that at less depth is still more irregular and weaker, probably arising from injury caused by wire worms. These experiments will be again repeated, and they are now only noted, not to show any conclusions that have been arrived at, but to point out how unsafe it is in agricultural experiments to generalize from a single set of experiments, as these are so liable to be interfered with by insects, climate, and a variety of causes.

c. When last year I had the pleasure of laying my notes upon these experimental plots before the Section of the British Association, the early period at which we met and the general lateness of the season prevented my being enabled to report upon some experiments in oat transmutation which the ripening of my crops subsequently showed to be of great interest; and as the interest consists in the fact that the *Avena fatua* has been made to assume the forms of different varieties of cereal or cultivated oats, I shall now detail the steps taken in bringing about this change*.

It is now six years since on a neighbouring farm, in a patch of seeding mangold wurtzels grown on forest marble, I observed an abundance of *Avena fatua*; and as this wild grass is a great pest, especially in clay districts, such as those on the Lias of the Vale of Gloucester and the Oxford Clay in Wilts, but comparatively rare on the Oolite brashes, I took a class of students to examine it and gather specimens for the Herbarium, at the same time giving them a field lecture upon this pest, in which I adverted to a tradition among the farmers of the Vale of Gloucester, that "they were prevented from growing oats because they degenerated into wild oats;" and it was with a view of determining if possible from experiment whether this notion was correct, that I afterwards gathered some of the ripe seed of the wild oat, which in the following spring I sowed in one of my plots. It came up very well, and the process was repeated the following season in another part of the garden, and in the autumn of 1855 I thought I remarked the following changes:—

1. A lighter-coloured fruit.

* Specimens of these changes accompanied the Report.

2. A less degree of hairiness when compared with the fruits of the true *A. fatua*.

3. A greenish coloured, straight and slight awn, instead of the black, bent at right angles, and twisted at the lower part of the very rigid awn of the wild plant.

4. The fruits were more frequently two than three perfect ones to each glume.

5. The fruits were much more plump, arising from a greater development of grain than in *A. fatua*.

6. The ripe fruits separated from the floral envelope less readily than in *A. fatua*.

In following out the experiments in the spring of 1856, the best specimens having been selected for seed were again sown; and in the month of September following, when this crop was gathered, the results were as under.

1st. *Avena fatua*, tolerably true, though perhaps not so coarse and strong as is usual on heavy clays.

2nd. *Avena fatua*, var. *sativa*, with a diffuse, spicate, pyramidal panicle, allied to the form called "Potatoe Oat," by farmers.

3rd. *Avena fatua*, var. *sativa*, with a compact panicle of flowers tending to one side, allied to the agricultural form known as "Tartarian Oats."

The two latter presented various shades of advance; a few of the more changed were awnless, but most of them possessed awns which were very coarse and rigid for what we may term "tame oats;" and the grain was by no means so plump as (when compared with its thick envelope) to entitle it to be called a good oat. However, it was sufficiently striking, and, on the whole, much more sudden in its advance than I had calculated upon. But to proceed.

In the present year, 1857, I planted the sorts, carefully separated, in separate patches of larger size, with the following result as to the crops.

a. The plot of *Avena fatua* is again mixed with many examples of the Potatoe form of oat, but none of the Tartarian type.

b. The Potatoe oats have a plumper seed and are much less awned; some examples are however still rigidly awned.

c. The Tartarian form is much larger than is usually grown in the best cultivation, its grain very fine, some awned, but mostly awnless.

Thus far then have these curious experiments proceeded. Next year they will be transferred to the field, in the hope of perpetuating these new varieties, as they promise to be much more vigorous than the older ones; and this indeed is one of the advantages in agriculture of new sorts, as, for a time at least, they usually succeed better than the older ones. But this is a matter I must not stop now to discuss.

It should be remarked that the shed seeds of the plot of 1856 were carefully dug in, in the hope that, by being allowed to deposit their seeds as in nature, the whole may again degenerate into wild oats; but only one specimen, and that of *A. fatua*, came up, for, having been so long submitted to cultivative processes (and the gathering and storing of seed previously to sowing is a very important one), they have little disposition to come up wildly afterwards, a fact which is more observable in some situations than in others; and acting upon this hint, I am not quite sure whether the best way to get rid of some weeds would not be to carefully cultivate them.

These experiments are of interest as showing what may be done in this direction towards elucidating some curious facts in vegetable physiology. They are no less so to the agriculturalist, as the remark of the old farmer, which was never a favourite one with the botanist, is now known to be true;

for if we can by experiment advance the wild oat to the cultivated state, so the cultivated by degenerating may relapse into the wild state. That the latter position is true, I had long known from an examination of the produce of shed oats around ricks and in fields, as some of these in a single year will be seen to possess a few hairs at the base of the fruit*, the awn will get longer and more rigid with a darker colour, and the seed much smaller. It would, however, take too long to pursue an inquiry into the agricultural speculations which these experiments might illustrate, and this perhaps may be better done when our crops are still further advanced; and I need therefore only to advert to such subjects as those involved in the growth of new sorts, the reasons for their value, and the facts connected with their maintenance, to prove this position.

d. Ægilops.—My three plots of this grass may be described as follows:—

1st. A permanent plot that is allowed to seed itself and *grow sporadically*, which it does with great freedom.

2nd. A plot of carefully picked seeds sown in autumn.

3rd. The same seeds sown in spring.

In reporting upon *Ægilops* last year, I remarked upon the difficulty of ripening the seeds. However, this is obviated, as the present condition of Plot 1 shows it to have become perfectly acclimatized. I had last year some reason to think I had made an advance towards proving the truth of M. Fabre's statement as to this being the parent of the cultivated wheat; but this year my examples have, if anything, retrograded. I shall therefore repeat the experiments in my own private garden, which is a distance from the College, and on a perfectly different soil. If M. Fabre's views be correct, I should have little hope of success where the plant grows so well and the circumstances seem so suitable for its maintenance in a wild condition, cultivation indeed consisting in the growing of plants in soils and situations unsuitable for them in their wild nature.

3. Papilionaceous Plants.—As regards this family, my experiments tend to show that many species may be made available for agricultural feeding purposes more than are at present employed; these however need not now be commented upon. I shall therefore confine myself to an account of experiments and observations on the following:—

Vicia angustifolia.	Narrow-leaved vetch.
Trifolium pratense.	Broad-leaved clover.
,, *medium.*	Ziczac clover.
Melilotus officinalis.	Common melilot.
,, *Taurica.*	Cabool clover.

In 1852 I collected seeds of *Vicia angustifolia* from the neighbourhood of Cirencester, which I sowed in a plot. In the spring of 1853, it came up well; but on flowering, only a few plants could be said to present the characters of the species as laid down in books, or indeed as afforded by the parents of these very specimens. The chief differences were much larger foliage, a greater length of stem, a tendency to two flowers in the axils of the leaf instead of a solitary one, and a great increase of size in the seeds. Now these distinctions did not exist in more than 20 per cent. of the plants; and as regards the difference in the seed, it may be remarked that it is rare to get a sample of seed of the *cultivated vetch* but will be very variable.

In 1854, I planted the seeds that were largest and most changed from

* I this year gathered a specimen from an old oat field on the Royal Agricultural College Farm with four white hairs at the base, and the seeds had a tendency to separate with the oblique scar, the grain still being plump.

the original, the resulting crop being in all particulars the *Vicia sativa* of authors.

In the autumn of the same year was planted a plot of the like selected seed and with the same result, affording stems as much as $2\frac{1}{2}$ feet in length, with leaflets half an inch broad, its original size being about 6 inches long, with leaflets a little more than the eighth of an inch broad.

From 1855, I have kept up a plot of each set, thus developing a *winter* and *spring* variety of *V. sativa* from *V. angustifolia*, whilst at the same time I have a plot in which the crop is permanently maintained by self-sown seeds; these, though larger than in wild nature, still preserve the rounded pods and small seeds with but little variation. The spring- and autumn-sown varieties are about as distinctive in appearance as are the agricultural forms of these.

Trifolium pratense.—This form in cultivation undergoes great changes, particularly in size and colour; it becomes many times larger, and its heads of flowers increase in size but are less bright in colour. This plant is found wild in all rich meadows and pastures; its place however in poor sandy soils where lime is absent is supplied by the *Trifolium medium*, on which account the latter plant was some few years since introduced into agriculture, to ensure a crop where the *T. pratense* usually failed. The seedsmen used to supply it under the name of *Trifolium medium*, its proper botanical designation; but it is a curious circumstance that all the samples of this seed now in the market are only those of a variety of *T. pratense*, and hence at present the best-informed seedsmen no longer send it out under the original designation of *T. medium*, the "cow grass" of the farmer, but with the name of *Trifolium pratense perenne*, the fact being now well established that we have two varieties of broad clover in cultivation, whilst the true *T. medium* * has been lost to agriculture until it be again introduced from wild plants; and the whole evidence with regard to this subject tends to show that it has not been lost from neglect, as it has been in constant cultivation; but it has gradually merged into the *T. pratense*; and at this present moment the so-called "broad clover" on the one hand and cow grass on the other are scarcely distinguishable, and seedsmen are constantly threatened with actions for supplying the wrong seed. This therefore remains as a matter for experiment, not only on account of the practical advantage of reviving the lost form to the farmer, but in order to settle the botanical question, as hitherto the botanist has never had a doubt of the distinctness, as species, of the *T. pratense* and *T. medium*†.

Melilotus.—Of these the *M. officinalis* and *M. Taurica* are kept up from self-sown seeds, as well as a plot of each drilled in rows the latter; I received some years since under the name of "Cabool clover," and I have since obtained the same from the seedsman with the designation of "Buchara clover:" they are probably only exotic forms of *M. leucantha* of the British flora.

The Melilots among the Papilionacea and the *Anthoxanthum odoratum* in the list of British grasses are alike remarkable for containing a peculiar aromatic principle, to which as it occurs in the latter the sweet smell of

* It may be well here to note that during the past week I have received some "cow-grass" from Cheshire, which has more of the details of the true *T. medium* than any I have yet seen: this case proves my position, because a great part of Cheshire has a subsoil of marine sand, the bottom of the old strait which separated England from Wales, and on this it continues; and hence I view it only as an arenaceous form of *T. pratense*. But this fact points out the propriety of getting cow-grass seed from the Cheshire sands.

† Seeds of *T. medium* from different localities would be highly valued by me. No seedsman can now supply the true form.

meadow hay is due, and is probably the cause of the superior quality of pasture hay when compared with that of the irrigated meadow, where this grass is seldom present, as also with hay of artificial grasses technically called seeds.

If flavour and, with this, superior quality, be imparted to hay by the presence of an aromatic species, would it not be well to mix a portion of melilot with clover and seeds? Cattle are exceedingly fond of it, and it is a plant which will grow readily and yield a large return in produce. To this end I have cultivated the common melilot, and should prefer it to the *M. Taurica*, on account of its less woody structure when mature.

These plants may be considered as biennial; however, by frequent cutting they may be made to last many years; and the following experiments in reference to this subject may be interesting, as showing the evil to the farmer of letting clovers (for it is the same with the *Trifolia*) remain too long before cutting.

A plot of *M. Taurica* of two years last summer had one-half of its rows kept cut down and not allowed to seed, the other half was seeded; and on the 4th of September, 1856, I made the following note:—

" *Cabool Clover.*—The cut-down rows about 18 inches high, fresh and green, and fit for cattle food; the rest in seed."

On the 1st of May, 1857, I made the following note:—

" *Cabool Clover.*—The cut portion a fine succulent plant, 8 inches high; the seeded part very thin, 3 inches high."

This year each of my clover plots will perform double experiments, as in them I am carrying on the same observations.

4. Green Feeding Crops.—In this list I would only advert to the *Symphytum*, and *Sanguisorba officinalis*.

The *Symphytum asperrimum* was introduced to this country as an ornamental plant from the Caucasus, by the Messrs. Loddige, as long ago as 1811, since when it has been recommended as a profitable green feeding or soiling crop for cattle, for which it seems adapted from its luxuriant growth and good feeding properties. It is a handsome plant, growing as much as 4 feet high, with an abundance of bright-blue bell-shaped flowers.

While experimenting on the growth of this plant, it struck me that the *Symphytum officinale* of our ditches would be equally valuable if it could be made to grow away from its natural habitat. With the view of testing this, I introduced an example of the white form of *S. officinale* from the River Churn in Cirencester, into my garden, which year by year has so nearly approached the *asperrimum* in its details, as to induce me to communicate the experiment to the British Association at a former meeting; and it was again commented upon in my notes of last year before this Section, when it was elicited from the Rev. J. L. Jenyns that "the *S. asperrimum* and *S. officinale* were growing together near Bath, and that it was now impossible to distinguish the one from the other." Here then I think I am justified in now saying that there can be no doubt of the specific identity of these two forms of plant.

Sanguisorba officinalis, on account of its astringent properties, may perhaps be considered as a useful plant for admixture with sainfoin and clovers, and to this end I have for years been anxious to try it as one of my experiments; but it is a curious fact as showing the position of the seed trade, that with as many as a dozen trials to procure it from as many seedsmen, and always under its botanical designation, I have never been able to obtain it, and all my plots have turned out *Poterium sanguisorba*, a plant of a different character, and which can only be considered as a weed: indeed the buyer of foreign sainfoin seed should be careful as to this plant, as in some samples

a large per centage of *Poterium* will be present. Three plots are now occupied with *Poterium*, the seed in all cases being labeled *Sanguisorba officinalis*, a circumstance showing either a great want of knowledge or a wilful substitution of the one for the other on account of a similarity of aspect and English name.

5. Esculent Vegetables.—A constant change in vegetable diet has always appeared to me to be a matter of such great importance, that I seldom miss an opportunity of making myself acquainted with the growth and capabilities of any new kind that may be introduced, as well as such as have nearly passed away on account of the favouritism shown from time to time towards new introductions; and as examples of what I am doing in that way I would notice the following:—

Potato Yam (*Dioscorea Batatas*) .	Among new introductions to this country.
A wild Potato	
The Yellow Lima Potato	
Salsafy	Among the all-but exploded vegetables.
Schorzonera	
Cardoons	

The potato yam is so much like our *Tamus communis*, as almost to lead to the inference of specific identity, judging from the vine and foliage, for I have not yet seen it in flower, much less in fruit. Its yearly increase of tubers seems to me too small to warrant its displacing the potato, for which it was recommended in the height of the disease of the latter plant. My plot in the Botanical Garden is not nearly so luxuriant as some specimens in my private garden, the latter being so much warmer and the soil considerably better. Here my plants of this year are climbing up sticks and are as much as 2 yards high; what the tuber will be remains to be seen; however, from my present experience I can only recommend it as an addition to the list of our culinary vegetables.

Last winter I was gratified at receiving a box of potato tubers which had been sent me by my friend Jenkin H. Thomas, Lieut. R.N., consisting of tubers of a "wild potato," and also some of a "Lima potato." The former appears to be a *Solanum*; but if of the species *tuberosum*, it is very different in all particulars from our cultivated form, the tubers of the latter are more like small kidney potatoes. But from the leaves and the slight indication of flower, I do not think it can be a Solanum at all; but I am informed that they are usually sold in Lima, so that I must make further inquiries into their previous history. I would now remark that a plot of them in my experimental garden has got on very badly, not more than five per cent. of the tubers growing, and that in a feeble state; however, three tubers planted in my private garden, though they were a long time coming up, are now very large plants, and in full vigour of growth.

As regards the wild potato, Lieut. Thomas writes as follows:—"I procured them from the top of a small island called San Lorenzo, opposite the anchorage of Callao and town of Lima, in Peru, and I have not the slightest doubt in my own mind but that they are the original potatoe, as the island is uninhabited, and fertile only at the top (an elevation of about 900 feet), where these potatoes grew: there is generally a mist over the top, and I think the temperature from 68° to 70°. The blossom is the same as our domestic one, but the leaf is prickly and rough; I cooked several of them when I was in Peru, but found them bitter and strong, but expect that cultivation and a couple of years' trial will totally eradicate that."—In a letter to the author of this report, Aug. 17, 1857.

The experiments with these in my garden at the College have been a comparative failure—however, about a tenth of them have come up,—whilst in my private garden the six tubers which I planted all came up well, and flowered and fruited too freely to expect much advance in the tubers; they came up quickly, and were in flower before the "Lima potatoes" (planted at the same time) showed above ground. They are now before me, and present the following appearance:—the original tuber has much enlarged, and small and imperfect young tubers stud the sides of the old one; they are very rough externally, and of a decidedly bitter taste. I have preserved the roots, and also a quantity of seeds, in order to carry on further experiments, as I see no reason why, in a short time, I should not procure a new variety of cultivated potato from this stock; but if these should afterwards present pinnate and bipinnate leaves, it will be interesting to mark the progress of change from the curious lobate leaf it now possesses.

The arriving at fresh potatoes from this source may do much to settle some questions regarding potato disease. It has been recommended to grow new varieties of this tuber from the apple or seeds, in order to procure a sound stock; but this in practice has failed, as seedling potatoes have been found to be as prone to disease as others. It is, however, possible that this may arise from the fact that the apples after all contain the seeds of an unsound race; and I shall therefore look with great interest to the result of the next few years in the growth and advance of this wild potato, and I hope I shall have two races going, one derived from the tubers, and another from the seeds.

Salsafy and Schorzonera are two capital roots, easy of cultivation, and which readily store during the winter. They are not, perhaps, so productive as carrots and parsnips; but they offer a good variation to these, both as a change of crop and also as food: formerly they were highly esteemed, but, like several other vegetables, they are now only found in the gardens of the curious.

Cardoons.—This is a vegetable very little grown in England, and yet it is of excellent quality, and not difficult of cultivation. Professor Lindley, in his 'Guide to the Orchard and Kitchen Garden,' p. 535, says, "The Cardoon (*Cynara Cardunculus,*) is greatly admired by many, and ought to have a place in every gentleman's garden; and yet it is curious how few of even gardeners have ever seen it." It progresses well on my plots, and I hope to experiment largely upon it in another season.

It may be well in this place to refer to some experiments which I have now been carrying on for nearly ten years in the ennobling of the wild parsnip. Of course it was known that our garden esculent was derived from the *Pastinaca sativa* of our fields; but the progress of the experiments has been marked by some interesting facts relating to malformations of roots known as finger-and-toe, and which will be found detailed in the 'Journal of the Royal Agricultural Society;' and at the same time it was a matter of no small interest to myself and pupils to note the great changes that took place as the experiments proceeded. The result has been the production of a good-sized parsnip of a regular shape, but containing more flavour than is perhaps desirable*; but, inasmuch as some people complain of the want of flavour in the ordinary cultivated parsnip, time may tone down my specimens to the requisite degree. I would remark that I sadly want a change of soil for continuing the experiments, and I have this year grown a quantity of seed; I

* During the time that my experiments have been in progress, I have been enabled to watch the downward progress of parsnips left from an abandoned garden; and though these have not even yet lost all traces of their civilization, they are essentially wild parsnips.

shall be happy to forward some to any members of the Association on application, only asking for the sake of information, any notes that may be made on its progress.

It is not a little curious that experiments of a like kind with the carrot have resulted in a failure. Upon reporting upon this last year, it was stated by Mr. Bentham, that Villemain had succeeded in advancing the carrot and some others, but had failed in all his experiments with the parsnip. This is curious, as showing that we cannot always command success in experiments of this nature—some circumstance or other may be wanting, and therefore we must not pronounce a thing impossible that we have tried ourselves without success; and at the same time it shows us that there are certain laws which operate to produce the changes we have noted, so that from a repetition of experiments of this kind we may hope to become acquainted with some new facts connected with vegetable growth.

An observation of some practical importance may be here noted. As a rule it may be laid down that neither parsnips nor carrots yield good roots in field cultivation in a district where these plants abound as wild natives, as they usually grow small and very much forked, digitated, "finger-and-toed;" and therefore, if grown as an agricultural crop under such circumstances, a much more careful preparation of the soil, even than that usually employed, will be necessary to ensure success; and thus it is that success is much more general with these roots in garden than in field culture.

But, besides, this own-grown seed tends much to degeneracy, especially in the field crop; and in the choice of seed we should always, if possible, choose that from a poorer soil and backward climate rather than in poor root soils to introduce a seed that had been grown in a district so much richer. These, indeed, may almost be considered as general laws.

6. Economic and Medicinal Plants.—The success which has attended my growing of many useful plants of this list in rough bits of ground, and otherwise waste corners of my garden, as well as in poor unmanured plots, is a matter of great interest, inasmuch as it shows that every bit of what is too frequently waste ground may be turned to account, and made to yield at least sufficient to pay the expenses, if not an overplus of profit; one item, however, the mere one of not losing, is gain, as cropping tends to get the land in workable condition.

In the economic class, such plants as flax, hemp, teasels, chicory and sunflower are all worthy of attention as being capable of yielding a good return, and often in most unpromising positions. I shall now, however, in this department only dwell upon some experiments in the growth of *Linum perenne* (perennial flax).

In 1854 I sowed one of my plots with seed of the *L. angustifolium* gathered at Hele in Cornwall. It came up very well, and in 1855 might have been seen its plants in rows with branches a few inches long trailing along the ground, some with light, others with dark-blue coloured flowers somewhat small when compared with the *L. usitatissimum* or *L. perenne*; in this state it presented little to recommend it as a cultivated plant. In the past year it had advanced to a strong and vigorous *upright* plant somewhat more than two feet in height, with handsome dark-blue flowers, indeed rivalling the *L. usitatissimum* in size and beauty. As regards its fibre I have as yet had no opportunity to make experiments; but if in this respect it should equal the annual flax, I cannot help thinking that we shall have in the *Linum perenne* a plant of great economic value.

As regards the specific distinction of the *L. angustifolium* and *L. perenne*, I must after these experiments express great doubts; nay, I am almost inclined

to think that *L. usitatissimum* is but an annual form of *L. perenne*, so that this year I shall collect the seeds of my perennial patch with a view of commencing an annual cultivation. At all events, should I fail in proving this point, we may fairly expect other changes of great interest, seeing that so much has already been done in bringing a little straggling linseed from its wild habitat, and cultivating in a different soil and climate, not by imitating its wild conditions, but by making for it a new soil, and planting in rows so that one row has the effect of inducing the upright growth to its neighbour, —a fact readily seen in examining the growth of my plant as its shoots first start in a trailing method—a circumstance which shows that in order to test the capabilities of some plants for a crop, we can only do so not by growing single specimen examples, but by planting a quantity side by side.

As subjects for experiment, it fortunately happens that the linseeds are readily affected by cultivative processes, so that we possess in them subjects capable of affording much information as the result of carefully conducted experiments, which leads me to remark that, as there are some tribes of plants which we cannot so easily act upon, permanency of our appointed species must not be concluded from the failure of our limited experiments, though, on the other hand, species must give way in those cases where as the result of properly conducted experiment the seed of one plant can be made to produce what has been considered as a distinctly specific form.

As regards medicinal plants, such specimens as *Hyoscyamus*, *Datura*, *Papaver album*, *Coriander*, and *Caraway* seem to do remarkably well in a not over-good soil and with but little trouble, so that where a market can be got for the produce, it might be worth while to attend to their cultivation, especially in corners.

I shall here only remark upon experiments with the *Datura Stramonium* and *D. Tatula*. A plot of each of these species was sown side by side, the former from seed grown in the district; the latter from seed kindly communicated by Mr. Savory the eminent apothecary and chemist, of New Bond-street. Of the former not one seed came up, whilst of the latter several plants at the time of my writing are in great perfection. I am informed by Mr. Savory that this species is highly valuable as a remedial agent, it being much more active and uniform in its action than the *D. Stramonium*; and he recommends it in the shape of cigars. Though these plants have been referred to under distinct names, there can, I think, be but little doubt that they are only varieties. The flowers of my specimens are but very slightly tinctured with purple. These plants are very abundant in the United States, the tinctured variety being much more common towards the South than in the Northern States, and it is not at all improbable that the want of colour in my specimens is the result of the cold, exposed climate of my garden, and poor soil in which I have planted them*.

7. WEEDS.—In this class I would notice the following plots:—*a. Allium vineale*; *b. Carduus acaulis* and others.

a. A plot was planted in the spring of 1856 with young plants of *Allium vineale* with the view of showing my class its method of growth, I pointing out to them how to get rid of so direful a pest. In the summer it had grown to good flowering heads, when, fearing lest it should overrun the garden, I had them pulled up and put into a weed fire to burn. The plot was left untouched until the spring of 1857, when to my astonishment young plants shot up, and the rows of this plot were as complete as in the former season. Upon reflection I saw in this a lesson which I had not my-

* Beck in his 'United States Botany' gives the *D. Tatula* as a variety of *D. Stramonium*. The former is called the Indian, and the latter the American thorn-apple.

self sufficiently studied; in order to explain which it will be necessary to point out that around the bulb of this plant, will be found from one to four bulblets, which at the time the plants begin to dry are easily separable from the parent: it therefore happened that upon pulling up the stem, the bulblets became detached and caused a thicker plant to spring up where I had thought it destroyed. This shows how even the pulling of a plant of this character is inefficacious for its destruction; and it may further be appealed to as one of those accidental experiments which almost every plot presents, for it may be observed that in these plots many facts (of agricultural interest especially) are daily unfolded by the College Garden experiments, that I have not commented upon in this report.

As regards the *Carduus acaulis*, it will here only be necessary to say that having found a new locality in Wilts. for *Carduus tuberosus*, I have brought a few specimens into my garden, and as will be seen from a separate paper which I have laid before the Section on this discovery, I have an idea that the *C. tuberosus* is but a hybrid. I am cultivating the *C. acaulis* and *C. acanthoides* side by side, in the hope of being able to prove this by experiment.

8. Flowering and Ornamental Plants.—These for the most part consist of such specimens as may be of use for teaching, or ornament in the lecture-room; and many of them afford interesting examples of departure from recognized typical forms as to be of value in teaching, whilst others seem to grow wildly and lose their whole cultivative characters. As yet I have not attended to the cultivation of flowers merely as illustrations of transmutation of species; but I am convinced that such genera as *Primula, Viola, Myosotis*, and *Malva*, &c., would furnish a vast amount of interesting matter as the result of time and attention bestowed on their investigation.

Here then, for this meeting, must end my notes; if, however, the Section should deem them, or the class of experiment they have reference to, worthy of continuation, the subject offers a field sufficiently wide, and, I think, important for much future investigation and description, as it appears to me that it is upon the noting and collecting such facts as can only be obtained where the subjects of them are under constant observation, that we can hope for much light being thrown upon the at present obscure subject of specific distinctions; and here, whilst experiments are being made upon this matter, it is not too much to state that other facts of great interest are constantly presenting themselves, so that while we are collecting evidence of a scientific kind we may also expect to make experiments tending to useful practical and economic discovery.

On the Resistance of Tubes to Collapse.

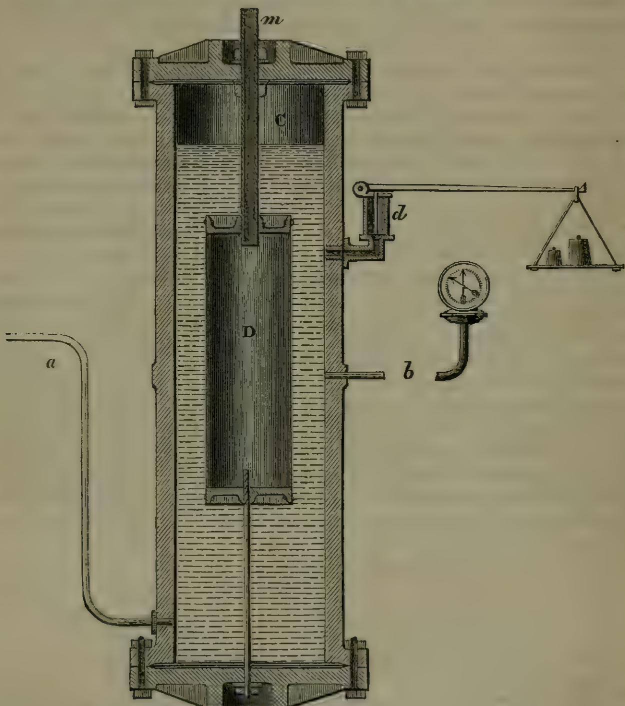
By William Fairbairn, *F.R.S.*

At the joint request of the British Association and the Royal Society, a series of experiments was undertaken to determine the laws which govern the resisting powers of cylindrical tubes exposed to a uniform external pressure, and from them to determine their strength, and deduce rules for proportioning the internal flues of boilers and similar vessels.

Hitherto it has been considered as an axiom of boiler-engineering, that a cylindrical tube placed in the position of a boiler flue, was equally strong in every part when subjected to a uniform external pressure, the length not

affecting the strength of a flue placed in such circumstances. This rule is, however, applicable only to tubes of infinitely great length, or to tubes unsupported by rigid rings at the extremities; it is very far from true where the length of the tube does not exceed certain limits, and where the ends are retained in a cylindrical form by being securely fastened in rigid frames to prevent their yielding to external pressure. Some experiments upon large boilers, with flues 20 to 30 feet long and about 3 feet diameter, first led to misgivings on this subject, by indicating the greater strength of the shorter flue. This anomalous result induced further inquiry, which not proving satisfactory, it was determined to submit the question to experiment, in order to prove how far these doubts were entitled to credit

To attain the objects of the experiments in a satisfactory manner, it was necessary that the apparatus for conducting them should be of great strength and large dimensions. For this purpose a cast-iron cylinder C, 8 feet long, 28 inches in diameter, and 2 inches thick of metal, was prepared for the



reception of the tubes to be experimented upon. A small pipe, *a*, was connected with a force pump, and by means of this, water was injected into the cylinder and the requisite pressure obtained. A second pipe, *b*, communicated with two steam pressure gauges, by which the force required for collapse was registered; and the indications of these were checked by a small and accurately fitted safety valve *d*. The large cylinder was fitted at top

and bottom with heavy ribbed covers, screwed to strong flanges on the cylinder, calculated to sustain great pressure. The tube to be experimented upon was fixed in the position shown at D, having cast-iron ends riveted and soldered to it to render it perfectly water-tight. The small tube *m*, communicating with the interior of the tube D, was for the purpose of allowing the escape of the contained air at the moment of collapse. The whole of the experiments were effected by means of the hydraulic pump, by which water was forced into the cylinder C; and the air, driven in a compressed state into the upper part, became highly elastic as the pressure was progressively increased until rupture took place. At very high pressures, the air in the cylinder C was permitted to escape, and collapse effected by water pressure only.

The tubes upon which the experiments were made varied from 18 inches to 60 inches in length; from 4 inches to $18\frac{3}{4}$ inches in diameter, and from ·043 to ·25 inch in thickness of metal. They were composed of plates of riveted sheet-iron, and the thinnest were carefully brazed at the joints to make them tight and prevent the entrance of water under pressure.

The results of the experiments may be stated under three heads: strength as affected by length, as affected by diameter, and as affected by thickness of metal.

I. *Strength as affected by Length.*—The results under this head are singularly interesting and conclusive. Within the limits of from 1·5 foot to about 10 feet in length, it is found that the strength of tubes similar in other respects, and supported at the ends by rigid rings, varies inversely as the length.

Thus, taking the four-inch tubes of different lengths, we have the following mean results derived from experiment:—

(1.) *Resistance of four-inch Tubes to Collapse.*

Diameter. ins.	Thickness of Plates. ins.	Length. ins.	Collapsing Pressure. lbs. per sq. in.
4	·043	19	137
4	·043	60	43
4	·043	40	65

The remarkable differences which exist in the resisting powers of the above similar tubes will be at once apparent. Assuming the experiment upon the tube 60 inches long to be correct, we may easily calculate the strength of the other 19- and 40-inch tubes, by the above-stated law of inverse proportion.

Thus, for the 40-inch tube, we have $40 : 60 :: 43 : x = 64$ lbs. And for the 19-inch tube,

$$19 : 60 :: 43 : x = 135 \text{ lbs.},$$

where the calculated differ from the experimental results by $\frac{1}{65}$th in one case, and $\frac{2}{137}$ths in the other.

(2.) *Resistance of six-inch Tubes to Collapse.*

	Diameter. ins.	Thickness. ins.	Length. ins.	Collapsing Pressure. lbs. per sq. in.
(1.)	6	·043	30	55
(2.)	6	·043	59	32

Here, from the data of experiment (1.), we may calculate the strength of a tube similar to that in experiment (2.)

$$59 : 30 :: 55 : x = 28 \text{ lbs.},$$

where the calculated differs from the experimental result by $\frac{1}{8}$th.

(3.) *Resistance of eight-inch Tubes to Collapse.*

	Diameter. ins.	Thickness. ins.	Length. ins.	Collapsing Pressure. lbs. per sq. in.
(1.)	8	·043	39	32
(2.)	8	·043	30	39

where from (1.) we have

$$30 : 39 :: 32 : x = 41 \text{ lbs.}$$

differing from the result in (2.) by $\frac{2}{39}$ths.

(4.) *Resistance of ten-inch Tubes to Collapse.*

	Diameter. ins.	Thickness. ins.	Length. ins.	Collapsing Pressure. lbs. per sq. in.
(1.)	10	·043	50	19
(2.)	10	·043	30	33

whence from (1.) we have

$$30 : 50 :: 19 : x = 31\tfrac{2}{3} \text{ lbs.}$$

or $1\frac{1}{3}$ lb. less than experiment (2.). In the same manner all the experiments might be taken and compared, and the law will be found to hold true in every case. The discrepancies are comparatively small, and, as they appear to follow no law, are evidently to be accounted for from defects in the construction of the tubes and difficulties in the mode of conducting the experiments, inseparable from such a mode of research.

II. *Strength as affected by Diameter.*—A precisely similar law is found to hold in relation to the diameter. Tubes similar in other respects vary in strength inversely as their diameters. Testing this law in the same manner as the last, we may at once place the calculated pressure beside that derived from experiment. Hence we have the following table:—

(1.) *Resistance to Collapse of Tubes five feet long.*

Diameter. ins.	Collapsing Pressure. lbs. per sq. in. By Experiment.	By Calculation.	Variation. lbs.
4	43		
6	32	28·6	−3·4
8	20·8	21·5	+0·7
10	16·0	17·2	1·2
12	12·5	14·3	1·8

The above variations are slight when compared with the resisting powers of the tubes. They were no doubt caused by the varying rigidity of the iron plates, or defects in the cylindrical form. Similarly we may take the results on tubes 30 inches long, and tabulate them in a similar manner.

(2.) *Resistance to Collapse of Tubes 2 feet 6 inches in length.*

Diameter. ins.	Collapsing Pressure. lbs. per sq. in. By Experiment.	By Calculation.	Variation. lbs.
4	84	78	−6
6	52		
8	39	39	0
10	33	31	2
12	22	26	+4

As before, the variation between the results calculated by the law from

the data of one experiment and those arrived at by actual collapse, will be seen to be very slight, and within the limits of error which might be anticipated.

III. *Strength as affected by the Thickness.*—It is found that the tubes vary in strength according to a certain power of the thickness, the index of which, taken from the mean of the experiments, is 2·19, or rather higher than the square.

Combining the above laws into a general expression, we get as the formula for the strength of tubes subjected to a uniform external force,

$$P=C\times\frac{k^{2\cdot19}}{L.D},$$

where P is the collapsing pressure, k the thickness of the plates, L the length of the tube, which should not be less than 1·5, or greater than 10 feet; D the diameter, and C a constant to be determined from the experiments. For tubes of greater length than above specified, a variable quantity dependent upon the length must be introduced; and the value of this has yet to be determined.

For ordinary practical calculations the following formula will probably afford the needful accuracy,

$$P=806{,}300\times\frac{k^2}{L\times D}.$$

Thus, for instance, take a flue 10 feet long, 2 feet in diameter, and composed of $\frac{1}{4}$-inch plates. Here the collapsing pressure

$$P=806{,}300\times\frac{\cdot25^2}{10\times24}=210\text{ lbs.}$$

per square inch nearly.

Some experiments have also been made upon elliptical tubes; and the results have been most conclusive as to the weakness of this form in resisting external pressure. No tubes in use for boilers should ever be made of the elliptical form.

With regard to cylindrical flues, the experiments indicate the necessity of an important modification of the ordinary mode of construction, in order to render them secure at the high pressures to which they are now almost constantly subjected. If we take a boiler of the ordinary construction, 30 feet long, 7 feet in diameter, and with one or more flues 3 feet or 3 feet 6 inches in diameter, it will be found that the outer shell is from three to three and a half times as strong in resisting an internal force, as the flues which have to resist the same external force. This being the case, it is evident that the excess of strength in those parts of the vessel subjected to tension, *is actually of no value*, so long as the elements of weakness are present in the other parts subjected to compression. To remedy these defects of construction, it is proposed that strong rigid rings of angle-iron should be riveted, at intervals, along the flue,—thus practically reducing its length, or in other words, increasing its strength to uniformity with that of the exterior shell of the boiler. This alteration in the existing mode of construction is so simple, and yet so effective, that its adoption may be confidently recommended to the attention of those interested in the construction of vessels so important to the success of our manufacturing system, and yet fraught with such potent elements of disaster when unscientifically constructed or improperly managed.

Report of the Proceedings of the Belfast Dredging Committee. *By* GEORGE C. HYNDMAN.

IN the comprehensive Report of the late Wm. Thompson, Esq., made in 1843, the Mollusca of Belfast Bay were so far elucidated that but few species have since been added, and it may be considered that little now remains to be done in that department but to generalize the results, which may be summed up at present by stating the numbers to be, of

Bivalves,	Acephala lamellibranchiata,	96 species.
Brachiopods,	Acephala palliobranchiata,	2 species.
Univalves,	Gasteropoda prosobranchiata,	96 species.
Univalves,	Gasteropoda opisthobranchiata,	11 species.
	In all	205 species.

Of the Tunicata, the Nudibranchs, and the Cephalopods, little or no further observations have been made since Mr. Thompson's report.

The Bay of Belfast is a wide open estuary, without any minor inlets and not diversified with any islands, except the Copelands, which lie at its entrance on the southern side. It is about seven miles wide between the extreme headlands, and within that space its depth does not exceed 10 fathoms. It is only beyond this line that the depth increases to 20 fathoms, and does not reach 50 fathoms till beyond the outermost of the Copeland Islands.

The only river of any magnitude deserving notice that flows into the Bay, is the Lagan, which enters at the extreme southern point, and has in the course of ages considerably changed that portion of the Bay, by the deposits of gravel, sand, and mud carried down. A very large area over which the tide once flowed has thus been gradually filled up; on it now stands a great portion of the town of Belfast, with its numerous manufactories, places of business, and the abodes of its stirring population. Evidence of this change occurs wherever excavations have been made for wells and foundations of buildings, sea sand and shells being generally found, sometimes at the depth of 30 feet and more in places further up the valley than where the town stands. Further down on either side of the Bay extensive changes have also taken place, by the gradual rising of mud banks covered with Zostera, where so lately as sixty or seventy years ago, people were in the habit of travelling along the strand at low water between Belfast and the villages of Holywood and White Abbey.

Whilst these changes had been going on at the upper end of the Bay, alterations of an opposite character were taking place on both sides still further down, where, as at Cultra and Ballyhome Bay on the Down side, and near Carrickfergus on the Antrim side, large portions of the land have been undermined and swept away. Without supposing any variation in the winds and tides, these latter changes may in part be accounted for by the continued drawing away of gravel and sand, and the removal of numerous detached rocks and reefs for building and other purposes, by which the shores have been more exposed to the action of the waves than formerly.

These changes in the bed of the sea must have had a corresponding influence upon the Mollusca, many species which inhabited the sandy and muddy tracts of shore having been covered up and killed; and several species have probably thus become extinct, as they are no longer found living: but on this point as yet there is only negative evidence, and the subject requires further investigation.

Mollusca of Belfast Bay.

Species.		Observations.
Lamellibranchiata.		
Teredo Norvagica	dead	Not known as living in the Bay. Found frequently in drift wood dug up in making sewers in Belfast, and in the excavations for the Harbour improvements.
Pholas dactylus	living	In variegated marl between high and low water near Carrickfergus: also on the County Down shore.
—— parva	dead	In submerged peat at the mouth of Conn's water, at the upper end of the Bay on the County Down side, by the late Dr. Drummond; at White House Point on the Antrim side by the Ordnance Survey Collectors.
—— crispata	living	In submerged peat at extreme low water in Bangor Harbour, County Down, and in other places.
—— ,, ...	dead	In the alluvial deposit at the head of the Bay, of very large size.
—— candida	living	On both sides of the Bay; between tide marks common.
Saxicava rugosa	living	Common from low water mark to 25 fathoms.
—— arctica	living	Not uncommon in the deeper water.
Mya truncata	living	Littoral, in mud.
—— ,, ...	dead	At various depths to 25 fathoms. Of very large size in the alluvial deposit.
—— arenaria	living	Littoral in sand and mud.
Corbula nucleus	living	In mud at 15 to 20 fathoms; not abundant.
Pandora obtusa	living	Off Castle Chichester and Black Head, in 15 to 20 fathoms; rare.
Lyonsia Norvegica	living	On both sides of the Bay, in from 8 to 12 fathoms.
Thracia phaseolina	dead	In the deeper water, scarce.
—— villosiuscula	dead	Off Groomsport, Edward Waller, Esq.
—— pubescens	dead	Recorded in Mr. Thompson's Report.
—— convexa	dead	Not uncommon in the alluvial deposit cut through in forming the new Channel, at a depth of 10 to 15 feet. Not known to be now living in the Bay; two specimens have been dredged off Black Head, broken, but with ligament fresh, so that it is probably still living; its habit of burrowing places it out of reach of the dredge.
—— distorta	dead	In limestone near Belfast, Mr. Grainger.
Cochlodesma prætenue ...	dead	In 20 fathoms off Black Head, valves united, rare. Recorded by Brown as found in the Bay.
Solen marginatus	dead	Off Bangor, County Down, and in alluvial deposits at the Quays.
—— siliqua	living	On both sides of the Bay. Very large and fine specimens from Ballyhome Bay, Mrs. Clealand.
—— ensis	living	On both sides of the Bay, and of very large size at the same place with the last.
—— pellucidus	living & dead.	Not uncommon in 6 to 20 fathoms.
Solecurtus coarctatus ...	dead	Rare, in 20 fathoms off Black Head; valves fresh and united.
Psammobia Ferroensis ...	dead	Rare, off Castle Chichester and Bangor, with valves united. In the alluvial deposits.
—— tellinella	dead	Rare, off Castle Chichester.
Tellina crassa	dead	Rare, in 10 fathoms off Castle Chichester, and also off Groomsport.
—— incarnata	dead	Very rare, off Castle Chichester.
—— tenuis	living	Not uncommon on sandy shores, both sides of the Bay.
—— fabula	dead	Rare, off Bangor.
—— solidula	living	Common in mud between tide marks.
Syndosmya alba	living	Rare in 8 to 10 fathoms.
—— ,, ...	dead	In the alluvium near Belfast.

Species.		Observations.
LAMELLIBRANCHIATA.		
Syndosmya intermedia ...	living	Rare, in the deeper water.
—— prismatica............	living	Rare, in 20 fathoms off Black Head.
Scrobicularia piperata ...	dead	Common in the alluvial deposit. At a depth of 30 feet, in sinking a well at Durham Street Mill. At 18 feet at Linfield Mill. On the muddy banks of the river Lagan nearly as far up as the tide now flows. Has not been found living, but is probably to be found.
Mactra solida..............	dead	A single valve dredged up off Castle Chichester, and odd valves off Bangor.
—— truncata	living	On sandy shores between tide marks.
—— elliptica...............	living	In 20 fathoms, not uncommon.
—— ,, ...	dead	In shell sand from deep water, common.
Lutraria elliptica	dead	On both sides of the Bay and in the alluvium, not uncommon. Probably living, but inaccessible to the dredge. Common in the alluvium.
—— oblonga...............	dead	Rare, in the alluvial deposit.
Tapes decussata...........	dead	Rare, in the alluvial deposit, of large size. Not known to be now living in the Bay.
—— pullastra	living	Common on both sides of the Bay.
—— ,, ...	dead	Abundant in the alluvium.
—— virginea...............	living	Not common, in from 10 to 20 fathoms.
—— ,, ...	dead	Common throughout the Bay at various depths, with the valves fresh and united, and also in the alluvium.
—— var. Sarniensis	living	Rare, off Bangor.
—— aurea..................	living	Common in sandy beaches between tide marks.
—— ,, ...	dead	In the alluvial deposits.
Venus casina	living	Frequent in 20 fathoms.
—— ,, ...	dead	Common in the deeper water. Not found in the alluvium.
—— striatula	living	Common from low water mark to 20 fathoms.
—— fasciata	living	Not uncommon from 10 to 20 fathoms on both sides of the Bay.
—— ovata..................	living	Rare, in 20 fathoms off Black Head.
—— ,, ...	dead	Abundant in shell sand from deep water.
Artemis exoleta...........	dead	Scarce, in about 10 fathoms on both sides of the Bay. On the shore at Cultra single valves are thrown up by the tide. Probably still living.
—— lincta.............. ..	dead	Not uncommon with the valves united on both sides of the Bay. Also in the alluvial deposits. Probably living.
Lucinopsis undata.........	dead	Not uncommon in 5 to 10 fathoms. Of very large size in the alluvial deposit.
Cyprina Islandica	living	Rare, in 20 fathoms.
—— ,, ...	dead	Frequent, of various sizes.
Circe minima...............	dead	Rare, in shell sand from deep water.
Astarte sulcata	living	Common in 10 to 20 fathoms, both sides of the Bay.
—— var. Scotica, smooth-edged	living	Rare, with the last.
—— triangularis	dead	Abundant in shell sand from deep water. A smooth-edged variety of this, as well as of the preceding. Query.—Can the difference be sexual?
Cardium echinatum	dead	Not common. In from 10 to 20 fathoms, valves often united.
—— edule..................	living	Common on sandy shores, but not in sufficient numbers to be gathered for sale.
—— nodosum	dead	Rare, in 10 to 20 fathoms.
—— pygmæum............	dead	Rare, in 10 fathoms.
—— Suecicum	dead	Rare, in shell sand from deep water.
—— Norvegicum	dead	Rare, in 10 to 20 fathoms.

Species.		Observations.
LAMELLIBRANCHIATA.		
Lucina borealis	dead	Not uncommon in 6 to 12 fathoms. Of large size in the alluvial deposits at Belfast.
—— spinifera	dead	Very rare, in 20 fathoms off Black Head, valves united.
—— flexuosa..............	dead	Rare, in 5 fathoms, and in the alluvial deposits.
Montacuta substriata......	living	Rare, on Spatangus purpureus, in 20 to 25 fathoms off Black Head.
—— bidentata	dead	Rare, off Bangor.
Turtonia minuta	living	Abundant between tide marks. Found in great quantity in the stomachs of Mullet taken in the Harbour near Belfast. In one fish taken in Larne Lough and the contents of the stomach given to me by W. Darragh, Curator to the Belfast Museum, I estimated 35,000 of these little shells.
Kellia suborbicularis......	dead	Rare, in mud from 10 fathoms.
—— rubra................	living	Common between tide marks.
Mytilus edulis	living	Very abundant on banks uncovered by the tide on both sides of the Bay. They were in former days very abundant on the banks off Holywood, when they were used as food, and also for bait. Now they have become less plentiful and not so good in quality, and are not so much sought after. Captain White, Harbour Master, tells me that in his early days it was a common saying that "Mussels and Hemp paid the Holywood rent." The Hemp was then grown for making fishing gear, but has long ceased to be so used. In Benn's History of Belfast, it is stated that in 1739 and the following year, in consequence of the great frost, crowds of wretched people from Belfast and other places assembled on the Warren at Holywood, and, pitching tents there, lived on the Mussels found on the banks. Mr. Patterson in his 'Zoology for Schools' records a similar case as having happened in 1792 or 1793, when about 20 families of poor people came from the interior of the country and encamped along the road-side and on the beach a short way to the west of Holywood. They remained there about five weeks, subsisting principally upon the mussels from the banks. Mussels grow very rapidly, as a vessel lying in the Old Channel for less than three months was found to be covered with them, fully an inch in length. They also attach themselves to the buoys, and even to the pilot-smack which is kept sailing through the Harbour.
Modiola Modiolus.........	living	Common at various depths from 6 fathoms. They are dredged up in from 6 to 10 fathoms off Groomsport, and used extensively as bait for Haddock and other fish. They are also eaten by the fishermen. Very commonly occupied by Pinnotheres pisum, the Pea Crab.
—— Tulipa	living	Rare, in about 10 fathoms and deeper.
Crenella discors............	living	Rare, at the roots of Antennularia and other zoophytes in from 10 to 25 fathoms.
—— marmorata	living	Very common imbedded in Ascidia mentula, and sometimes moored by a byssus to shells and seaweed.
—— decussata	dead	Rare, in shell sand from 27 fathoms; valves united.
Nucula Nucleus............	living	Common in muddy ground from 5 fathoms and deeper.
—— nitida	dead	Rare, in shell sand from 27 fathoms.
—— radiata	living	Rare, off Groomsport. Edward Waller, Esq.

Species.		Observations.
Lamellibranchiata.		
Leda caudata	dead	Rare, in 20 to 25 fathoms off Black Head.
Arca tetragona	living	Imbedded in a pebble of black limestone in 50 fathoms, off the Copeland Islands.
—— ,,	dead	Rare, in shell sand from 27 fathoms.
—— lactea	dead	Rare, with the preceding.
Pectunculus glycimeris	living	Rare, in 10 to 20 fathoms off Castle Chichester and Black Head.
—— ,,	dead	Abundant at the same place. Small-sized single valves common in shell sand from deep water.
Pinna pectinata	living	Rare, in 25 fathoms off Black Head. Pearls were found in one specimen, of a brown colour like the shell.
Lima subauriculata	dead	Very rare, in shell sand from 27 fathoms.
—— Loscombii	living	Rare, in 20 fathoms and deeper. Makes a nest for itself like *hians*, but often occurs without any. The animal swims vigorously through the water. The late James Rose Clealand, Esq., of Rathgael House, discovered this shell many years ago off the Copeland Islands, and was aware of its making a nest. He was one of the earliest dredgers in this bay.
—— ,,	dead	Common in shell sand from deep water.
—— hians	dead	A single valve found in the alluvial deposit by Dr. Wm. M'Gee; also recorded as found by the Ordnance Survey Collectors in 7 fathoms; but the shell has never occurred in any of our late dredgings.
Pecten varius	living	Not common, in about 10 fathoms.
—— Pusio	living	Not uncommon among dead shells from 10 to 12 fathoms. Sometimes found inside a bivalve shell closely fitting to its concavity.
—— tigrinus	living	Rare, in 20 fathoms and deeper.
—— ,,	dead	Single valves not uncommon in shell sand from deep water.
—— similis	dead	Rare, in shell sand from 27 fathoms.
—— maximus	living	Not uncommon in some localities. Mr. Hugh Gray, an intelligent and experienced dredger and fisher from Groomsport, tells me that these shells may be taken in great numbers off Ballycormick Point close to the shore in 7 to 10 fathoms, and also along the Antrim coast and round the Copeland Islands. They are seldom sought for exclusively, but taken in the search for oysters, as they bring a very small price in the market.
—— opercularis	living	Abundant in some places and generally diffused through the Bay, at various depths from 7 to 20 fathoms. Mr. Gray says they are sometimes taken in great numbers in trawling, by their shell fastening upon the net. They are also sometimes taken by the dredge and brought to market, but the price is so low as not to remunerate the fishermen.
Ostrea edulis	living	Abundant at various depths from near low water mark to 25 fathoms. Attains a very large size and a great age, if the number of layers of shell be taken as a criterion. Those that are taken in this Bay have long been esteemed for their good quality under the name of Carrickfergus Oysters. The following information has been given me by Mr. Hugh Gray. There are various beds through the Bay on which Oysters may be had. One near the Lighthouse in about 1 to $1\frac{1}{4}$ fathom. Other beds are from 2 to 8 fathoms. About four years ago a bed was discovered

Species.		Observations.
LAMELLIBRANCHIATA.		near the Copeland Islands in 14 fathoms, now nearly dredged out. This is the greatest depth at which Oysters are generally taken for sale, but Mr. Gray has known them brought up on the long lines from 45 fathoms, of large size and good quality. Oysters generally prefer hard ground, that is, where stones and dead shells are to be found to which they can attach themselves; they are of better quality on such ground than on mud. He has seen their spawn, but knows nothing of their age, nor how long they are in attaining their full size. The number of boats employed in dredging has diminished of late years, more owing, Mr. Gray thinks, to a falling off in price than to any scarcity of the Oysters, which are now imported in considerable quantities from Greencastle, Stranraer, and Whitehaven. The highest price he has known the fishermen to obtain was 21*s.* per 120. They are now down to 7*s.* for the best, and have been so low as 3*s.* when not of the best quality.
		No attempt has been made to establish artificial beds in Belfast Bay.
Anomia ephippium	living	Common on oysters, scallops, and other shells at various depths. Upper valves of large size are sometimes found with laminaria attached.
—— aculeata...............	living	Not very common, on laminaria.
—— patelliformis	living	Frequent on shells from 10 to 20 fathoms.
—— "	dead	Common in shell sand from deep water.
—— striata	dead	Same as the last.
BRACHIOPODA. ACEPHALA PALLIOBRANCHIATA.		
Terebratula caput serpentis.	living	Very rare. Recorded as having been taken by the Ordnance Survey Collectors off White Head. Has not occurred to any of us since within the Bay, although found in deeper water outside.
—— " "	dead	Rare, in shell sand from deep water.
Crania anomala	dead	Rare, in shell sand from deep water, found living in the deep water north of the Bay.
GASTEROPODA PROSOBRANCHIATA.		
Chiton fascicularis.........	living	Determined by the late W. Thompson, Esq., and published in his Report under the names by which they were then known.
—— ruber..................	living	
—— cinereus	living	
—— asellus	living	
—— albus	living	
—— cancellatus	living	
—— lævis	living	
—— marmoreus	living	
Patella vulgata	living	Common on rocks and stones between tide marks. Within the Bay they are not much sought after as food; but at Groomsport Mr. Gray informs me they are so used, and also as bait for Codling. Captain White, Harbour Master, tells me that they are found to be good for eating and wholesome on the outer coast of County Down, but that in Strangford Lough they are found not to be wholesome, and are avoided by the people there.
—— pellucida	living	Common, burrowing into the stems of *Laminaria digitata*. In the young state on the leaves of the same plant. The thin variety seems only to be found on rocky shores.

Species.		Observations.
GASTEROPODA PROSOBRANCHIATA.		
Acmæa testudinalis	living	Frequent on both sides of the Bay on rocks and stones near low water mark. First discovered as a British shell by the late James Rose Clealand, Esq., and named after him by Sowerby, but it was afterwards found to have been previously described and named by Müller.
—— virginea...............	living	Rare, on oysters and dead shells from 10 fathoms.
Propilidium ancyloide ...	dead	Scarce, among the shell sand from 27 fathoms.
—— ,, ...	living	In 90 to 100 fathoms off the Maidens.
Dentalium entalis	living	Common in from 5 to 20 fathoms.
Pileopsis Hungaricus......	living	Rather scarce, among oysters and dead shells in 10 to 20 fathoms.
Fissurella reticulata	living	Scarce, in similar situations with the last.
Puncturella Noachina ...	dead	Rare, in shell sand from deep water.
Emarginula reticulata ...	living	Common at various depths from 5 to 25 fathoms.
—— ,, ...	dead	Frequent in shell sand from deep water.
—— crassa	living	Very rare, in 60 fathoms off the Copeland Islands.
—— ,, ...	dead	Rare, in shell sand from 20 fathoms and deeper.
Trochus ziziphinus	living	Common from Laminarian zone to deep water. The white variety, Lyonsii, is occasionally found.
—— granulatus...........	dead	Very rare. Two broken specimens dredged up at separate times in the Bay; but as there are only two other examples known of its being found so far from its usual southern habitat, these have been no doubt introduced accidentally.
—— millegranus	living	Rather scarce, in from 10 to 20 fathoms.
—— ,, ...	dead	Abundant in shell sand from deep water. First taken in this neighbourhood by the late J. R. Clealand, Esq.
—— Montagui	living	Off Groomsport. (Edward Waller, Esq.)
—— ,, ...	dead	Rare, in shell sand from deep water.
—— tumidus...............	living	Rare, in from 10 to 20 fathoms.
—— cinerarius	living	Common between tide marks and a little deeper.
—— umbilicatus	living	Common between tide marks.
—— magus	living	Common in some situations on both sides of the Bay from low water mark to 10 fathoms.
—— helicinus	living	Common on *Laminaria digitata*, &c.
Phasianella pullus	living	Frequent near low water mark.
—— ,, ...	dead	Common in shell sand from deep water.
Adeorbis subcarinata......	dead	Rare, in shell sand from deep water.
Scissurella crispata	dead	Very rare, in same shell sand as last.
Ianthina communis	living	Rarely found so far south in the Channel, but occasionally abundant on the shore at Portrush and the Giant's Causeway.
Littorina Neritoides	living	Common near high water mark.
—— littorea	living	Common on rocks between tide marks on both sides of the Bay. Very abundant on banks on both sides of the channel leading to the Harbour, from whence the Periwinkles are gathered and exported in large quantities to London. Mr. Getty, Secretary to the Harbour Commissioners, informs me that this trade has been carried on for the last 25 years by one person, who employs three horses and a mule to draw them, besides employing boats, &c., paying about £60 weekly in wages during the season. The Periwinkles are assorted and put into sacks, of which one hundred are often shipped by one steamer weekly. The quantity exported in 1854 amounted to 400 tons, and in 1855 to 459 tons. During this long period

Species.		Observations.
GASTEROPODA PROSOBRANCHIATA.		
		there appears to have been no diminution in the supply until this last season, when it is stated they are not so plentiful as formerly.
Littorina littorea	dead	In the alluvial deposits. I have found these shells in a sandy beach on the banks of the Blackwater (Blackstaff), nearly two miles beyond the present highest reach of the tide.
—— rudis	living	Common on rocky ground a little below high water mark.
—— patula	living	Common in similar localities as the last.
—— littoralis	living	Common among fuci on rocks and stones between tide marks.
Lacuna pallidula	living	Common on laminaria.
—— vincta	living	Same as the last.
—— crassior	living	Rather rare, on laminaria, &c., in deeper water than the two preceding.
Rissoa striatula	dead	Rare, in shell sand from deep water.
—— Zetlandica............	dead	Rare, with the last.
—— crenulata	dead	Rare, do.
—— calathus	dead	Rare, do.
—— Beanii	dead	Abundant, do.
—— punctura	dead	Scarce, do.
—— costata	dead	Scarce, do.
—— striata	dead	Abundant, do.
—— ,, ...	living	Common between tide marks.
—— parva..................	living	Common on sea-weed.
—— ,, ...	dead	Common in shell sand.
—— interrupta	living	Common between tide marks.
—— labiosa	living	Abundant on banks where Zostera grows.
—— rufilabrum............	living	Scarce on seaweed between tide marks.
—— cingillus	living	Common under stones near low water.
—— ulvæ	living	Profusely scattered over the muddy shores left dry between high and low water. In summer it is the chief food of the grey Mullet, which is taken in the channel leading to the Docks. In winter various sea-birds feed upon it.
Skenea planorbis	living	Common on seaweed near low water. Found also in the stomachs of grey Mullet.
Turritella communis	living	Frequent in from 10 to 20 fathoms.
—— ,, ...	dead	In the alluvial deposits, of much larger size than any now found living.
Cæcum glabrum	dead	Rare, in shell sand from deep water.
Aporhais pes pelecani ...	living	Common in 10 to 25 fathoms.
Cerithium reticulatum ...	living	Abundant on the muddy banks between tide marks.
—— ,, ...	dead	Common in the alluvial deposits.
—— adversum	dead	In shell sand from deep water.
Scalaria Turtoni	dead	Rare. In the alluvial deposits; in one instance several were found together. Not known as now living in the Bay.
—— communis	dead	Rare in shell sand from deep water.
—— clathratula	dead	Rare, with the last.
Aclis unica..................	dead	Very rare, same as last.
Eulima polita...............	dead	Rare, in deep water.
—— distorta...............	dead	Rare, in shell sand from deep water.
—— bilineata	dead	Not uncommon, with the last.
Chemnitzia rufescens......	dead	Rare, off Groomsport. (Edward Waller, Esq.)
Odostomia unidentata ...	dead	Rare, in shell sand from deep water.
—— plicata	dead	Rare, Bangor.
—— eulimoides............	dead	Rare, in shell sand from deep water.

Species.		Observations.
GASTEROPODA PROSOBRANCHIATA.		
Odostomia interstincta ...	dead	Rare, with the last.
—— spiralis	dead	Rare, with the last.
Natica monilifera	dead	Not common, off Bangor.
—— nitida..................	living	Rare, in about 10 fathoms.
—— "	dead	A small white polished variety, or a distinct species, is common in shell sand from deep water.
—— Montagui	dead	In 20 fathoms.
Velutina lævigata	living	Rare, in 15 to 20 fathoms.
Lamellaria perspicua......	living	Rare, on Laminaria.
Trichotropis borealis......	dead	Rare, in shell sand from deep water.
Cerithiopsis tubercularis	dead	Rare, with the last.
Murex erinaceus	living	Rare, in deep water.
Purpura Lapillus	living	Common on rocks between high and low water mark, sometimes found in deep water.
Nassa reticulata............	living	Occasionally found in 10 to 20 fathoms.
—— incrassata	living	Common in 8 or 10 fathoms.
—— "	dead	Common in deep water. In 30 fathoms off the Copelands, many specimens were found very bright in colour, and fresh, but all inhabited by *Paguri.*
Buccinum undatum	living	Abundant from low water to 50 fathoms.
—— "	dead	In the alluvial deposit and at various depths. At Groomsport they are taken by means of baskets baited with fish garbage, and sunk in any convenient depth, and are used as bait for taking codfish. They are never eaten here by the fishermen or poor people. In this locality they are called Buckies, as are also *Fusus antiquus.*
Fusus Islandicus............	living	Not uncommon at various depths.
—— antiquus	living	Common at various depth, principally in the deep water. Taken for bait along with *Buc. undatum.* A singular convoluted variety was dredged off Groomsport this season by Samuel Vance, Esq. No part of the spire is visible except the few solid whorls at the apex. Exhibited at the Meeting of the Association, and since published in the Dublin Natural History Review.
Trophon clathratus	living	Occasionally found in 6 to 10 fathoms on both sides of the Bay.
—— muricatus	dead	Rare, off Groomsport and in the deeper water.
—— Barvicensis	dead	Rare, in 8 or 10 fathoms.
Mangelia turricula.........	dead	Frequent in 5 to 6 fathoms.
—— rufa	living	Rare, off Groomsport. (Edward Waller, Esq.)
—— septangularis	living	Rare, in 10 fathoms.
—— "	dead	Occasionally in deeper water.
—— purpurea	dead	Rare, in shell sand.
—— linearis	dead	Rare, in same.
—— nebula	dead	Rare, in same.
—— costata	dead	Rare, in 10 fathoms.
Cypræa Europæa	living	Not uncommon from low water to 20 fathoms.
—— "	dead	Frequent at various depths.
—— *moneta*	dead	Specimens of this shell have been frequently found on the shore near Bangor, County Down. Although not indigenous, its occurrence may be worth noticing, as there is a tradition that a ship engaged in the slave trade was wrecked there, and thus the Cowries are accounted for.

Species.		Observations.
GASTEROPODA OPISTHO-BRANCHIATA.		
Cylichna cylindracea......	dead	Rare, in shell sand.
—— truncata	dead	With the last.
—— obtusa	dead	With the last.
—— umbilicata...........	dead	With the last.
Tornatella fasciata.........	dead	Rare, off Bangor, and in shell sand.
Akera bullata...............	living	Abundant on the Zostera banks. Sometimes thrown up on the Kinnegar, Holywood, in great numbers. I have sometimes seen it swimming in the channel leading to the Quays, giving out a purple liquid when touched.
Bulla Cranchii	living	Very rare. A single specimen from Groomsport many years ago; none since.
Scaphander lignarius......	living	Not uncommon of large size off Groomsport in 6 or 8 fathoms, and in other places.
—— "	dead	Occasionally found at various depths.
Philine aperta	living	Plentiful, occasionally in a few fathoms.
Aplysia hybrida...........	living	Rather scarce, in 8 or 10 fathoms, off Bangor and Groomsport, and in Castle Chichester Bay.
Pleurobranchus membranaceus.	living	Scarce, off Groomsport in 6 or 8 fathoms and in other places.

In the course of their various proceedings in dredging, the Committee were aided by several gentlemen amateurs, who lent their yachts for the purpose and otherwise assisted; and in the year 1856 they were joined in their labours by Edward Waller, Esq., whose cooperation has proved of great service in determining species.

In 1850 Mr. Getty and Mr. Hyndman had first become aware of a deposit of fine shell sand in about 27 fathoms at the entrance of the Bay, which produced several rare species of shells, *Propilidium ancyloide, Puncturella Noachina, Scissurella crispata, Adeorbis subcarinata, Rissoa Beanii, Terebratula caput serpentis,* and *Crania anomala,* all dead; and in 1852 further research led to the discovery of a great submarine bank known to the fishermen as "the Turbot Bank," lying a short distance out from the cliffs called the Gobbins, on the coast of Antrim, and extending from the Isle of Muck across the entrance of Belfast Bay towards the Copeland Islands. Fishing by means of long lines had formerly been successfully carried on upon this bank within the recollection of some of the fishermen, but has been given up for several years, as the fish, from whatever cause, do not now frequent the bank.

This locality having been further explored in 1856 during a dredging excursion, a quantity of sand was brought up so rich in shells that it was thought desirable to have a list made out. With this view the sand was examined by Mr. Waller, Dr. Dickie, and Mr. Hyndman. Some of the species more difficult to determine have been named for Mr. Waller by the kindness of Joshua Alder, Esq.; such species are marked A, including *Mangelia Holbollii,* an interesting addition to the British fauna.

The Turbot Bank lies in about 25 to 30 fathoms; the ridge is composed of gravel and broken shells, more or less fine, the finer being in the top, while the edges towards the deeper water are made up of coarse rolled pebbles derived from the rocks of the adjoining coast, and found by Messrs. McAdam and Bryce to consist of Trap, Marl, Greywacke, Porphyry, Quartz, Flint, Sandstone, and Coal,—the last no doubt from the passing vessels.

The following is a summary of the species:—

Acephala lamellibranchiata	83
—— palliobranchiata	2
Gasteropoda prosobranchiata	97
—— opisthobranchiata	11
In all	193

List of Shells from the Turbot Bank.

Those marked A. determined by J. Alder, Esq.

Species.			Observations.
Pholas *striata*	very rare	dead	2 single valves only found. It is not admitted as a British shell by Forbes and Hanley, and it is no doubt an introduced species in shipwrecked Mahogany.
Saxicava arctica	scarce	dead.	
—— rugosa	frequent	dead.	
Mya truncata	scarce	dead	Fragments mostly.
—— arenaria	scarce	dead	Fragments only.
Corbula nucleus	scarce	dead.	
Sphœnia Binghami, A.	rare	living.	
Pandora obtusa	rare	dead.	
Lyonsia Norvegica	rare	dead.	
Thracia phaseolina	scarce	dead.	
—— pubescens	scarce	dead.	
Cochlodesma prætenue	rare	dead.	
Solecurtus coarctatus	rare	dead.	
Psammobia Ferroensis	rare	dead.	
—— tellinella	scarce	dead	Valves united.
Tellina crassa	rare	dead.	
—— donacina	rare	dead.	
—— incarnata	rare	dead.	
—— tenuis	scarce	dead.	
—— fabula	rare	dead.	
—— solidula	rare	dead.	
Syndosmya alba	scarce	dead.	
—— intermedia	scarce	dead.	
—— prismatica	scarce	dead.	
Mactra elliptica	common	...	A few living, dead shells common.
Lutraria elliptica	rare	dead	Fragments only.
Tapes pullastra	scarce.	...	
—— virginea	common	dead	Sometimes with valves united.
—— aurea	rare.	...	
Venus casina	common	dead	Sometimes with valves united.
—— striatula	frequent	dead	Sometimes with valves united.
—— fasciata	scarce	living	Single valves not uncommon.
—— ovata	frequent	dead	Occasionally living, single valves very frequent.
Artemis exoleta	scarce	dead.	
—— lincta	scarce	dead.	
Lucinopsis undata	scarce	dead.	
Cyprina Islandica	common	dead	From the smallest size up to full-grown, valves often united.
Circe minima	scarce	dead.	
Astarte sulcata	frequent	...	Living occasionally, single valves common.
—— var. Scotica	frequent	dead	Single valves of small size.

Species.			Observations.
Astarte triangularis	very frequent	...	Living, rare; valves united common, single valves very frequent.
—— var.	......	...	Like *sulcata*, there is a smooth-edged var. of this. Quære, is the difference sexual?
Cardium echinatum	......	dead.	
—— edule	......	dead.	
—— nodosum	......	dead.	
—— fasciatum	......	dead.	
—— pygmæum	......	dead.	
—— Suecicum	......	dead.	
—— Norvegicum	......	dead.	
Lucina borealis	......	dead.	
—— spinifera	rare	dead.	
—— flexuosa	rare	dead.	
—— leucoma	rare	dead.	
Montacuta substriata......	frequent	living	On *Spatangus purpureus*.
Turtonia minuta.			
Kellia suborbicularis.			
—— rubra.			
Mytilus edulis	not common	...	Small-sized single valves.
Modiola Modiolus	frequent	living	On the edge of the bank.
—— tulipa?	scarce	dead	Single valves.
Crenella discors............	scarce	dead.	
—— marmorata	not common	dead.	
—— decussata	rare	dead.	
Nucula Nucleus............	common	dead	Both valves entire, frequent.
—— nitida	scarce	dead.	
Leda caudata...............	frequent	dead.	
Arca tetragona	scarce	dead.	
—— lactea..................	scarce	dead.	
Pectunculus glycimeris...	common	dead	Full-sized with valves united frequent. Single valves of various sizes abundant. Very rarely alive, and only small-sized specimens.
Pinna pectinata............	rare	... ...	Living specimens have been taken by trawling. Fragments sometimes found.
Lima Loscombii	frequent	...	Single valves and fragments common.
—— subauriculata	rare	...	Single valves.
Pecten varius...............	......	...	Single valves.
—— pusio	......	...	Single valves.
—— striatus	......	...	Single valves (Dr. Dickie).
—— tigrinus	frequent	... ...	Living on the edge of the bank. Single valves common.
—— Danicus?	rare	...	(Dr. Dickie).
—— similis	scarce	...	Single valves.
—— maximus	scarce	...	Single and broken valves.
—— opercularis	common	...	Small-sized single valves common.
Ostrea edulis	......	...	Fragments and broken shells.
Anomia ephippium	frequent	...	Single valves.
—— aculeata...............	scarce	...	Single valves.
—— patelliformis	scarce	...	Single valves.
—— striata	frequent	...	Single valves.
Terebratula caput serpentis	frequent	... ...	Living in the deep water, single valves not uncommon.
Crania anomala	scarce	...	Same as the last.
Chiton asellus	......	living.	
Patella vulgata	not common	dead.	
—— pellucida	frequent	dead.	
Acmæa virginea...........	frequent	dead.	
Pilidium fulvum	rare	dead	Dr. Dickie.

Species.			Observations.
Propilidium ancyloide ...	frequent	dead	In the fine shell sand taken in 1850 numerous. Scarce ever since.
Dentalium entalis	frequent	dead.	
Pileopsis Hungaricus......	scarce	dead	Of small size only.
Fissurella reticulata	rare	dead.	
Puncturella Noachina ...	rare	dead.	
Emarginula reticulata ...	common	dead.	
—— crassa	rare	dead.	
Trochus zizyphinus	frequent	dead.	
—— millegranus	abundant	dead.	
—— exiguus	......	...	Dr. Dickie, doubtful.
—— Montagui	frequent	dead.	
—— tumidus...............	frequent	dead.	
—— cinerarius	not common	dead.	
—— umbilicatus	scarce	dead.	
—— magus.			
—— helicinus.			
Phasianella Pullus.........	frequent	dead.	
Adeorbis subcarinata......	scarce	dead.	
Scissurella crispata	very rare	dead	In the fine shell sand only.
Littorina littorea	not common	dead.	
—— littoralis	not common	dead.	
Lacuna pallidula	scarce	dead.	
—— Puteolus	scarce	dead.	
—— vincta	very frequent	dead.	
—— crassior	scarce	dead.	
Rissoa striatula	rare	dead.	
—— Zetlandica, A.	rare	dead.	
—— crenulata, A..........	rare	dead.	
—— Calathus, A.	rare	dead.	
—— Beanii, A.............	abundant	dead	Determined also by Mr. Hanley.
—— punctura, A..........	scarce	dead.	
—— costata	scarce	dead.	
—— striata	common	dead.	
—— parva, A.	frequent	dead.	
—— interrupta	scarce	dead.	
—— labiosa	scarce	dead.	
—— inconspicua, A.......	scarce	dead.	
—— semistriata	scarce	dead.	
—— Cingillus	scarce	dead.	
—— proxima...............	scarce	dead.	
—— ulvæ	frequent	dead.	
Skenea planorbis	rare.	dead.	
Turritella communis	frequent	dead.	
Cæcum glabrum	rare	dead.	
Aporhais pes pelecani ...	scarce	dead.	
Cerithium reticulatum ...	frequent	dead.	
—— adversum	scarce	dead.	
—— Metula	very rare	dead	A single specimen by Mr. Waller.
Scalaria communis	rare	dead.	
—— clathratula	rare	dead.	
Aclis supranitida	very rare	dead.	
—— unica..................	very rare	dead.	
Eulima polita..............	rare	dead.	
—— distorta, var. gracilis	rare	dead.	
—— bilineata	frequent	dead.	
Chemnitzia elegantissima	scarce	dead.	
—— fulvocincta, A.	rare	dead.	
—— rufescens, A..........	rare	dead.	
—— indistincta, A.	rare	dead.	
Odostomia conspicua, A...	......	dead.	

Species.			Observations.
Odostomia unidentata ...	......	dead.	
—— acuta, A.	......	dead.	
—— eulimoides, A.	......	dead.	
—— plicata, A.............	......	dead.	
—— interstincta, A........	......	dead.	
—— spiralis, A.............	......	dead.	
Natica nitida	frequent	dead.	
—— monilifera	scarce	dead.	
—— Montagui	rare	dead.	
Velutina lævigata	scarce	dead.	
Trichotropis borealis......	scarce	dead.	
Cerithiopsis tubercularis..	scarce	dead.	
Murex erinaceus	rare	dead.	
Purpura lapillus............	not common	dead.	
Nassa reticulata............	scarce	dead.	
—— incrassata	scarce	dead.	
—— pygmæa?	rare	dead	(Dr. Dickie.)
Buccinum undatum	frequent	dead	Fry very common.
Fusus Islandicus	frequent	dead	Very common.
—— antiquus	frequent	dead.	
Trophon clathratus, A. ...	frequent	dead.	
—— muricatus, A.........	frequent	dead.	
—— Barvicensis, A.......	scarce	dead.	
Mangelia turricula, A. ...	scarce	dead.	
—— rufa, A.			
—— septangularis.			
—— teres	rare	dead	Fragments.
—— linearis, A.			
—— nebula.			
—— striolata.			
—— costata, A.			
—— Holbollii, A.	rare	dead	This rare shell, new to the British list, was first discovered in shell sand dredged up in 1856. It was distinguished at once by both Mr. Waller and Mr. Hyndman as differing from any species described by Forbes and Hanley, and was determined by Mr. Alder.
Cypræa Europæa	frequent	dead.	
Ovula patula	very rare	dead	A single specimen (Mr. Waller).
—— acuminata............	very rare	dead	Ditto (ditto).
Cylichna cylindracea......	rare	dead.	
—— truncata	scarce	dead.	
—— obtusa	scarce	dead.	
Tornatella fasciata.........	scarce	dead.	
Bulla Cranchii	very rare	dead	A single specimen each to Dr. Dickie and G. C. H.
Scaphander lignarius......	rare	dead.	
Philine aperta	scarce	dead.	
—— scabra	rare	dead.	

It will be seen from the foregoing list that with few exceptions the shells are dead and many of them inhabitants of deep water; it therefore became an object of interest to discover the locality from whence they were derived, and this may now be considered to be ascertained. In Admiral Beechey's Hydrographic Survey there is indicated a deep recess in the Channel not far distant from an extensive ridge of rocks lying off the entrance to Larne Lough, on which the two Maidens Lighthouses are erected. Here in a limited area is a depth of from 80 to 100 fathoms; but it is difficult for

dredging operations, owing to the strong current of the tides and the eddies formed by the sunken rocks. After several unsuccessful attempts to reach this region by Mr. Getty and Mr. Hyndman, the latter was at length, in 1856, enabled to accomplish his object through the kind assistance of Captain Hoskyn, R.N., then engaged in completing the Survey, and who brought to the task the experience gained under the late Captain Graves, R.N., while dredging in the Ægean. A few hauls of the dredge produced *Terebratula caput serpentis* and *Propilidium ancyloide* alive, besides some rare Crustacea and Zoophytes. In 1857 a steamer was engaged, and a day spent in further explorations, the result of which is now given; but it is evident that further investigation in this locality is desirable and likely to repay the labour.

List of Species taken in deep water, 70 to 100 fathoms, off the Maidens Lighthouses, 1856 and 1857.

Species.		Observations.
Scaphander lignarius	dead	A single broken specimen.
Cypræa Europæa	dead.	
Trophon muricatus	dead.	
—— clathratus	dead.	
Fusus antiquus	living	Small sized, 70 to 100 fathoms.
—— Islandicus	dead.	
Buccinum undatum	living	Small sized, 70 to 100 fathoms.
Nassa incrassata	living	90 fathoms, several dead with Paguri.
Trichotropis borealis	dead.	
Velutina lævigata	living	90 fathoms.
Natica Montagui	dead.	
—— nitida	dead.	
Trochus millegranus	living	100 fathoms.
—— zizyphinus	living	100 fathoms.
—— tumidus	living	100 fathoms.
Emarginula crassa	dead.	
—— reticulata	dead.	
Pileopsis Hungaricus	dead.	
Dentalium entalis	dead.	
Propilidium ancyloide	living	100 fathoms.
Chiton asellus	living	70 fathoms.
Terebratula caput serpentis	living	70 to 100 fathoms.
Crania anomala	living	70 to 90 fathoms.
Anomia striata	dead.	
—— ephippium	living	70 fathoms.
Pecten opercularis	dead.	
—— tigrinus	living	75 fathoms, very fine.
—— Pusio	dead.	
Lima Loscombii	living	75 fathoms.
Pectunculus glycimeris	living	90 fathoms, small size.
Nucula Nucleus	dead.	
Leda caudata	living	90 fathoms.
Crenella marmorata	living	In Ascidia mentula, 75 fathoms.
Modiola Modiolus	living	90 fathoms.
—— tulipa	dead	Valves united, 75 fathoms.
Cardium pygmæum	dead.	
Astarte sulcata	living	70 to 90 fathoms.
—— —— var. Scotica	living	70 to 90 fathoms.
Circe minima	dead.	
Venus ovata	living	70 fathoms.
—— casina	living	70 fathoms.
Syndosmya alba	dead.	

Species.		Observations.
Saxicava arctica	living	75 fathoms, at roots of *Sertularia*.
Ascidia mentula	living	75 fathoms.
Verruca Stromia	living	90 fathoms.
Balanus porcatus (Scoticus)	dead.	
—— crenatus	living	75 fathoms.
Hyas coarctatus	living	70 fathoms, small sized.
Ebalia Pennantii	living	90 fathoms.
Munida Rondeletii	living	90 fathoms.
Pagurus Thompsoni ?	living	90 fathoms.
—— lævis	living	90 fathoms.
—— Hyndmanni	living	90 fathoms.
Serpula triquetra	dead.	
Amphidotus roseus	living	90 fathoms.
Spatangus purpureus	living	90 fathoms, very small sized.
Echinocyamus pusillus	living	90 fathoms.
Echinus sphæra	living	90 fathoms.
Solaster papposa	living	100 fathoms, very small size.
Ophiocoma bellis	living	70 fathoms.
—— rosula	living	75 fathoms.
Comatula rosacea	living	75 to 100 fathoms.
Cyathina Smithii	living	75 fathoms.

Several Zoophytes taken with the foregoing have yet to be fully examined, for which purpose they are in the hands of Professor Wyville Thomson, who has observed among them a new form of *Sertularia*.

Zoophytes received from the North of Ireland.
By Professor Wyville Thomson, Queen's College, Belfast.

ZOOPHYTA HYDROIDA.

Tubularina.

Fam. 1. *Corynidæ*.

Clava (Gmelin).

C. multicornis, Font. Very common on seaweed between tide-marks. Belfast Bay, Strangford Lough, &c. Constantly diœcious. The males distinguished from the females by the lighter and brighter colour of the reproductive organs. In this species the Medusoid zooid is not developed. A very variable species.

Hydractinia.

H. echinata, Flem. sp. Common on old shells, usually associated with a *Pagurus*.

Coryne.

C. pusilla, Gaut. Abundant on seaweed between tide marks and on Zoophytes in the Coralline zone.

Eudendrium.

E. rameum, Pall. Frequent in Belfast Lough. A specimen dredged off the Gobbins. Mr. Hyndman.

E. ramosum, Ellis. Frequent in Belfast Lough. Off Crawfordsburn, male and female. In this species both male and female individuals developed Medusoid zooids. These zooids sometimes become early disengaged, and sometimes remain attached until the male and female generative products are fully matured.

I have met with one or two other small species of this genus, but have not had an opportunity of examining them fully.

TUBULARIA.

T. indivisa, L. In deep water. Common.
T. Dumertieri. On *Flustra truncata.* Belfast Bay.
T. Larynx. "Belfast and Strangford Loughs."—*Wm. Thompson.*

Sertulariadæ.

THOA.

T. halecina, L. Common. Belfast Bay, &c.
T. Beanii, Johnst. Common. Belfast Bay, &c. &c. In the male the aperture of the vesicle is placed at or near the apex; in the female near the centre of the capsule.
T. muricata, Ellis. A specimen in the late Wm. Thompson's Collection, marked "Newcastle, Co. Down."

SERTULARIA.

S. polyzonias, L. Common.
S. rugosa. Common.
S. rosacea. Not very common. Belfast Lough.
S. ——. Allied to *rosacea.* Dredged off Bangor, Co. Down.
S. ——. Allied to *rosacea.* A specimen dredged by Mr. Hyndman off the Gobbins, Co. Antrim. A specimen procured previously by myself in Lamlash Bay, Arran.
S. pumila. Very common. In some cases, at all events, the testes of this species, developing parent-cells and spermatozoa, are thrown out in a gelatinous envelope from the mouth of the capsule; and the female organs forming ova without intermediate "zooids," are retained within the ovarian vesicle till mature.
S. Pinaster. Frequent in Belfast Bay, &c.
S. Tamarisca, L. Belfast Bay, &c.
S. abietina, L. Common.
S. filicula, Ellis. Rare. In the late Wm. Thompson's Collection.
S. operculata, L. Common.
S. argentea, Ellis. Common.
S. cupressina, L. Magilligan Strand. (Templeton.)

THUIARIA.

T. Thuia, L. North Coast of Ireland. (Wm. Thompson.)
T. articulata, Pall. Belfast Lough, Coast of Co. Down.

ANTENNULARIA.

A. antennina, L. Common.
A. ramosa, L. Common.

PLUMULARIA.

P. falcata, L. Common.
P. cristata, Lam. On *Halidrys siliquosa.* N. Coast of Ireland. (Wm. Thompson.)
P. pinnata, L. Frequent.
P. setacea, Ellis. Frequent.
P. Catharina, Johnst. Belfast Bay.
P. myriophyllum, L. White Head near Carrickfergus. M'Calla.
P. frutescens, Ellis. A specimen dredged off the Gobbins by Mr. Hyndman.

Campanulariadæ.

LAOMEDEA.

L. dichotoma, L. Common.
L. geniculata, L. Very common.
L. gelatinosa, Pall. Common.
L. Flemingii, Milne-Edwards. Common.
L. lacerata, Johnst. Deep water.

CAMPANULARIA.

C. volubilis, Ellis. Common.
C. Johnstoni, Alder. Common.
C. Hincksii, Alder. In deep water. Common.
C. verticillata, L. Not common. Belfast Bay.
C.? ? dumosa, Flem. Very common.
Coppinia arcta, Dalyell, sp. On *Plumularia falcata*.
Halia reticulata, Wy. T. On *Sertularia abietina*. Common.

The following POLYZOA, from the deep water near the Maidens Rocks, have been determined by the Rev. Thomas Hincks:—

Tubulipora hispida.
—— serpens.
Cellepora pumicosa.
—— Skenii.
Hippothoa catenularia.
—— divaricata.
Flustra foliacea.
Membranipora Flemingii.
—— coriacea.
Lepralia Malusii.
—— Hyndmanni.
—— simplex.
Lepralia reticulata.
—— fissa.
—— ciliata.
—— labrosa.
—— annulata.
—— innominata.
—— auriculata.
—— Brogniartii.
—— linearis.
—— coccinea.
—— pertusa.
—— spinifera.

FORAMINIFERA. Belfast Bay.

Professor Williamson having expressed a wish to be supplied with some of the sand dredged up from different depths and localities in order to ascertain the Foraminifera of the district, a quantity was accordingly forwarded to him; and the following list has been obligingly furnished of the different forms obtained by him from the sand, which he pronounces not rich in these organisms:—

Lagena vulgaris.
—— var. clavata.
—— var. perlucida.
—— var. striata.
Entosolenia marginata, young.
—— squamosa.
Polystomella crispa.
—— umbilicatula.
Rotalina Beccarii.
—— globularis.
Globigerina bulloides.
Planorbulina vulgaris.
Truncatulina lobatula.
Bulimina pupoides, var. fusiformis.
Polymorphina lactea.
Textularia cuneiformis.
Biloculina bulloides.
—— var. carinata.
—— var. Patagonica.
Spiroloculina concentrica.
Miliolina seminulum.
—— var. oblongum.
—— bicornis, var. angulata.
Spirillina foliacea, young.

The Belfast Dredging Committee for 1858, are Professor Dickie, Professor Wyville Thomson, Mr. Patterson, and Mr. Hyndman.

On the Mechanical Effect of combining Girders and Suspension Chains, and a comparison of the weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load. By PETER W. BARLOW, *F.R.S.*

MY attention has been recently directed to this subject from having been required to investigate, as engineer of the Londonderry and Enniskillen, and Londonderry and Coleraine Railways, the best mode of effecting a junction between the lines at Londonderry, to be combined with an improved road communication, for which an Act has been obtained by the Corporation of the city; and the Commissioners having determined to advertise for plans, leaving the decision to Sir William Cubitt, an engineer justly occupying a position so eminent, and in whose judgment I had the greatest confidence, I determined to submit the result of my investigation to him, although the principle which I concluded would best meet all the circumstances of the case, viz. the suspension girder, was one with reference to which considerable prejudice had existed.

Sir William Cubitt, after devoting much attention to the subject, has fully sanctioned the principle, and recommended the Bridge Commissioners to carry out my design, with some modifications suggested by him.

In order to verify my calculations, I have caused a series of experiments to be made, the results of which are of so much practical importance, and so fully confirm my investigations, that I determined to lay them before the British Association, in order that the simple question of the mechanical effects of combining a girder with a suspension chain, on which no difference of opinion ought to exist, should be fully decided; but before describing these experiments I will make a few general remarks upon the systems which have been adopted in bridge constructions.

General remarks upon the construction of Bridges of large span.—Bridges may be divided into three classes:—

1st. The Arch, a structure in which the supporting material is subjected to compression alone, but which contains no rigidity in itself.

2nd. The Suspension Bridge, in which the supporting material is subjected to extension alone, which also contains no rigidity in itself; and

3rd. The Girder, in which the material is subjected to both extension and compression, of which there are two varieties; one, which is subjected to diagonal strains, as the lattice, Warren, and tubular girders; and a second, in which all the strains are confined to the upper and lower webs, as in the bow and string; and Mr. Brunel's new girder, which is a combination of an arch and a suspension chain, each doing half the supporting duty.

This second variety is the most simple form, but has no more rigidity in itself than an ordinary arch or suspension bridge.

Of these three systems, the girder necessarily requires, from combining compressive and extensive resistances, a much larger amount of metal than either of the other systems, which will be rendered evident by a simple investigation, and by reference to existing structures.

In an ordinary arch the compressive force is resisted by the abutments, which in no way add weight or strain to the metal; but if the arch is converted into a girder, it can only be done by adding a tie-bar, the arch having then to support its own tie or substitute for an abutment, in addition to its own weight.

In a suspension bridge the tensile force is resisted by back chains, and if these are taken away to make it a girder, a compression-tube or bar has to be used as a substitute for them (as in the Chepstow bridge), which tube

becomes in large spans, with its supports, by far the largest portion of the structure, and destroys the bridge by its own weight, the weight of metal being fully doubled to produce equal strength, and quadrupled to produce equal stiffness, if loaded equally all over.

The great difference in weight produced by this and other causes will be seen by comparing suspension girder bridges with ordinary girder bridges; and I will take as an example the case of the two largest railway openings yet constructed, the Niagara suspension girder bridge, and compare its weight of metal with that of the Britannia Tube.

The quantity of material in the Niagara Bridge, having a roadway and a single railway of three gauges in a span of 820 feet, is in round numbers 1000 tons, and the weight in the Britannia Tube of 460 feet span 3000 tons for a double line.

If the Britannia Tube had been made on the same principle as the Niagara Bridge, the quantity of material to give the same strength and rigidity would not have exceeded $\frac{1}{6}$th part of what has actually been employed.

So great a difference in the weight renders it obvious that the principle of an ordinary girder involves great extra material, and it became an interesting and important inquiry to ascertain the cause of this difference.

The view that has hitherto been generally adopted on this subject, is that advanced by Mr. E. Clark in his work on the Britannia Tube, in which he states, speaking of the proposal to use the Menai suspension bridge for railway purposes,—"With respect to the use of the present suspension bridge for the proposed traffic, it was found difficult to devise any means of sufficiently strengthening it that did not involve an almost entire reconstruction, and great difficulty was similarly found in attempting to render any suspension bridge sufficiently rigid for railway traffic, by means of ordinary trussing.

"When the passing load is small compared to the weight of the chains and of the structure itself, there is indeed no difficulty; but the construction of a platform 450 feet long, sufficiently rigid for railway traffic, almost amounts to the construction of the tube itself."

Although unsupported by fact or experiment, this theory has been received and acted upon, not only by a large portion of the public, whose impressions of suspension bridges are derived from what had hitherto been constructed of insufficient strength, and without being combined with a girder, but it has been received and acted upon by engineers of eminence in this country.

These experiments, however, distinctly prove that a suspended girder, as designed for the Londonderry Bridge, is rendered equally rigid with less than $\frac{1}{25}$th of the metal required in the girder alone, so that the most important economy arises from the combination of a girder with a chain.

Experiments on Suspension Girders.—I have had the model accurately made, which is now submitted to the meeting, on a scale of $\frac{1}{33}$rd part of the actual span, the length being $13' \, 6''$ between the bearings,—a length exceeding that of the average of the models used by the Iron Commissioners in their experiments, and is amply sufficient, due allowance being made for the scale, to determine with accuracy the deflections on the actual girder, although the deflections of the chains will be somewhat more on the model than on the girder, from the weight not being sufficient to bring the surfaces into perfect contact.

The principal object of the experiments was to ascertain the deflection of the wave of a girder attached to a chain, as compared with the deflection of the same girder detached.

This being obtained, it was perfectly easy to arrive at the deflection of the wave of the Londonderry Bridge, because we have sufficient experiments on girders to enable a calculation to be made of what the Londonderry girder

would deflect without the chain, which being obtained and reduced in the ratio of the girder attached to the girder detached, gave the true deflection.

My first intention was to make the experiments with a girder which was a correct model of the actual bridge, which would have indicated $\frac{1}{33}$rd of the actual deflection, but I found the deflection of the wave to be so small that it was difficult to measure it with sufficient accuracy, and I therefore had a wooden box made of the correct depth, with the sides as thin as it would stand, viz. $\frac{1}{4}$ deal plank, in order to obtain greater deflection of the wave, with the correct depth of the girder, and with the chain attached to it as in the proposed bridge.

I could no longer obtain the actual deflection of the Londonderry Bridge by multiplying the experimental deflections by 33, but knowing that the deflection of a model on the correct scale would be $\frac{1}{33}$rd of the Londonderry girder, and knowing by experiment how much the model was deflected when unattached, the actual deflection of the Londonderry girder is obtained by reducing the observed experimental deflection in the ratio of the rigidity of the actual model to a true model, and then multiplying by 33.

The deflections of this girder, taken without the chains attached, with a weight of 168 lbs. on the centre, was ·75 of an inch; with the chain attached, and with the weight placed $\frac{1}{4}$ from the high tower, it was as follows:—

lbs.	$\frac{1}{4}$ from High Tower. in.	Centre. in.	$\frac{1}{4}$ from Low Tower. in.
56	·030	·010	·010
112	·060	·040	·010
168	·075	·040	·010
	Experiment 2.		
56	·030	·020	·000
112	·050	·040	·005
168	·075	·050	·005

The ratio of the deflection of the wave at $\frac{1}{4}$th the distance, where the greatest amount arises when the chain is attached, to that in the middle when not attached, is as 1 to 10 only; but it was evident from the large deflection at the centre and from no rise occurring at the opposite end, that the girder was too rigid to indicate the wave, and that the deflection observed was greatly due to the chain not coming to its bearing.

I therefore decided, in order to magnify the wave and make its amount more distinct, to have a girder made of angle-iron $\frac{1}{8}$ inch thick and a quarter the depth of the former girder, but simply suspended from and not attached to the chain.

The deflection of this girder without the chains, with a load of 42 lbs. placed on the centre, was 1·2 inch.

The deflections of the wave with the chain attached, and 227 lbs. distributed over the girder when the weights were placed at $\frac{1}{4}$ from the high tower, were with—

lbs.	$\frac{1}{4}$ from High Tower. in.	Centre. in.	$\frac{1}{4}$ from Low Tower. in.
56	—·10	—·01	+·05
112	—·20	—·04	+·12
168	—·28	—·06	+·16

Experiment 2.—In this case the weights were placed $\frac{1}{4}$ from the low tower.

56	+·06	—·01	—·12
112	+·15	—·05	—·25
168	+·18	—·07	—·36

The deflections here averaged ·32 inch with 168 lbs., equal to ·08 inch with 42 lbs., or $\frac{1}{15}$th the deflection of the girder without the chain.

The deflection of the Londonderry girder, deduced from the mean results of the deflections of the Boyne Viaduct and Newark Bridge and the Britannia Tube (see Appendix A), was 33 inches with 100 tons in the centre, $\frac{33}{15}=2{\cdot}20$ inches, the deflection here indicated in the Londonderry Bridge with 100 tons placed at a quarter the length of the girder.

It was still obvious from the deflection at the centre and little rise exhibited in the wave, that the stretching of the chain to bring the metal surfaces to bear, still sensibly influenced the result, and I had another wooden girder made, consisting of a plank $7\frac{1}{2}$ inches in width and $\frac{3}{4}$th of an inch thick, in order still more to magnify the wave, and to diminish the error from the stretching of the chain.

The deflection without the chain attached was 1·48 inch with 10 lbs.

Experiments with the Chain attached.—With 56 lbs. placed at $\frac{1}{4}$ from the high tower on the girder which was previously quite unloaded, the deflections were at—

$\frac{1}{8}$ from H. T.	$\frac{1}{4}$ from H. T.	$\frac{3}{8}$ from H. T.	$\frac{1}{2}$ from H. T.	$\frac{5}{8}$ from H. T.	$\frac{3}{4}$ from H. T.	$\frac{7}{8}$ from H. T.
−·31	−·48	−·32	−·02	+·22	+·29	+·15

Experiment 2.—70 lbs. being equally distributed over the girder, and 56 lbs. at $\frac{1}{4}$ from high tower—

−·28	−·42	−·25	+·04	+·23	+·28	+·20

Experiment 3.—150 lbs. all over weight in same place—

−·20	−·35	−·20	+·02	+·20	+·23	+·14

Experiment 4.—193 lbs. equally distributed, 56 lbs. as before—

−·18	−·31	−·17	+·05	+·18	+·20	+·14

The deflection here indicated with the model loaded with a weight representing 96 tons on the bridge (which experiment was several times repeated), was ·31 with 56 lbs. $=$ ·055 with 10 lbs., or $\frac{1}{26}$th of the deflection of the girder without the chain; $\frac{33}{26}=1{\cdot}27$ is therefore the deflection of the wave indicated by the experiment of the Londonderry Bridge, with a load of 100 tons at $\frac{1}{4}$ from the tower.

To obtain the comparative rigidity of the experimental girder, we have here as—

206 lbs. : 10 lbs. : : 1 in. : ·0485, the deflection of a true model with 10 lbs.; $\frac{1{\cdot}48}{{\cdot}0485}$ or $\frac{1}{30{\cdot}5}$ represents the rigidity of the experimental girder; $\frac{{\cdot}31}{30{\cdot}5}\times 33=$ ·335, the deflection by a weight on the bridge of $56\times 33^2=27$ tons.

27 : 100 : : ·335 : 1·27, the deflection as previously calculated.

This result being so much at variance with the general view of the subject, although very nearly in accordance with my calculations, I determined to verify it by a smaller girder, 6 inches by $\frac{3}{4}$ths of an inch thick, which would render the wave still more visible, the observations being made with great nicety.

The deflection at the centre when not attached to the chain was 2·375 inches with 8 lbs.

Girder attached to the chains, 193 lbs. being equally distributed over it. The deflection, with the weight placed $\frac{1}{4}$ from the high tower, was—

lbs.	$\frac{1}{4}$ from H. T.	Centre.	$\frac{1}{4}$ from L. T.
56	−·64	+·13	+·53

Experiment 2.—With 56 lbs at the centre of the bridge the deflection was −·30.

The deflection of the wave here exhibited at $\frac{1}{4}$th of the length with the bridge loaded to a weight equivalent to 100 tons on the actual bridge, which

experiment was repeated several times with the same result, was 0·64 inch with 56 lbs., the deflection without the chains being 2·375 with 8 lbs., or 25 times the amount.

In determining how far this result was effected by the resistance produced by the change of figure in the curve of the chain, I removed all the weights from the plank, and found the result as follows, with 56 lbs. at $\frac{1}{4}$ from the high tower:—

$\frac{1}{4}$ from H. T.	Centre.	$\frac{1}{4}$ from L. T.
−·85	+·20	+·75
With 56 lbs. placed $\frac{1}{4}$ from low tower—		
+·81	+·12	−·86

From this experiment it appears that the deflection is decreased by loading the bridge to $\frac{1}{20}$th of that of the girder unattached, and if the chain were without weight it would be still further reduced; in practice, however, the weight on the bridge will much exceed that on a model, and $\frac{1}{25}$th will be the least amount that will arise, a result so at variance with the preconceived notions of many engineers, that it is to be expected in some instances it will be received with incredulity; but an investigation will show that the result is in accordance with the law $\frac{l^3w}{bd^3x}$=a constant quantity.

If the girder were supported only in the middle, the deflection of the half girder would be $\frac{1}{8}$th, but as one half of the girder cannot deflect without the other half rising, from the action of the chain, it is reduced to $\frac{1}{16}$th; but the girder is not supported at one point only, but at various points, which will still further reduce the deflection.

However, whether this view is precisely the correct one or not, the fact is established, that the deflection of the wave of a girder attached to the chain and loaded as in the actual bridge, will not exceed $\frac{1}{25}$th of the same girder without the chain, from which we may estimate the weight of girder sufficient to produce in a suspension bridge or arch the requisite rigidity.

In order to show the importance of this result in the cost of bridges, I will compare the deflection and weight of metal in a bridge similar to the Londonderry Bridge, with a girder of equal span, in each case assuming that 3 tons per foot on the bridge will bring no strain exceeding 5 tons per inch on the metal.

The weight of chain, such that 3 tons per foot on the girder will not exceed 5 tons per inch, is (see Appendix B)	150 tons.
The weight of girder sufficient to give no wave or deflection greater than 1·32 in. with 100 tons (see Appendix A)	150 „
The weight of metal in cast-iron columns, so that the greatest compression with 3 tons per foot is 4 tons per inch (see Appendix C)	60 „
Weight of suspension bars, so that the tensile strain does not exceed 5 tons per inch with 3 tons per foot load (see Appendix D)	15 „
	375
To this must be added the value of the cost of the anchorage of the chains, which in the Londonderry Bridge will be 15 per cent. of the iron-work of the main girder portion of the bridge, so that I have added 57 tons to represent the value of the cost	57 „
	432 tons.

To compare this weight with that of a girder alone of the same length and depth as that used, which would be equally rigid with the suspension girder, we have to multiply $150 \times 25 = 3750$ tons, or more than eight times the amount of metal; but it may be correctly argued that a simple girder would be made deeper, and it is therefore fairer to make the comparison with an actual girder, of which we have an example nearly the same span in the Britannia Tube.

The weight of the pair of the Britannia Tubes is 3100 tons, or more than seven times the amount, a difference which will be received with surprise; but it is perfectly consistent with the fact that the Derry Bridge has nearly three times the depth, and has 2660 tons less of its own weight to support.

The weight of metal in the Londonderry Bridge does not in fact exceed that of the sides of one of the Britannia Tubes without the top and bottom webs.

It should be observed that the proportion of the cost of anchorage will vary under different circumstances, but in the case of the Londonderry Bridge it will be under 15 per cent.

It should also be noticed, on the other hand, as a set-off to the cost of anchorage, that the foundations will be increased in a girder bridge, from their having to support 3110 tons as compared with 432 tons in the suspension bridge, which will produce an amount in saving in average cases equal to the anchorage.

We will now compare the rigidity of the suspension bridge with that of the tube.

The deflection from 1 ton per foot all over the suspension bridge (see Appendix A) will be $1\frac{1}{2}$ inch.

The deflection of one of the Britannia Tubes from 1 ton per foot all over is $3\frac{1}{4}$ inches.

The greatest wave that will be produced by a train of 200 tons covering one-half of the Londonderry Bridge, the other portion being unloaded, will be readily found from the experiments.

The calculated extreme deflection of the girder with 200 tons all over, separate from the chain, is 41·25 inches (see Appendix A): $\frac{41 \cdot 25}{25} = 1 \cdot 65$, the greatest deflection of the wave if simply suspended from the chain; but, as the chain in the actual bridge is attached to the girder for nearly one-half the length, the rigidity will be much greater than here indicated.

It thus appears that the deflection of the Londonderry Bridge, with a suspended girder and loaded all over, equals the wave when the bridge is half loaded, and they are each about half the deflection of one of the Britannia Tubes when loaded all over with the same weight per foot.

It is necessary to explain, that the estimate given of the deflection of the Britannia Tubes assumes that they act separately; when united at the top they become suspension girders, and the deflection is reduced; on the other hand, it has to be noticed that I have not taken into account the increased rigidity from uniting the girder to the chain, instead of simply suspending it, which will have a most material influence.

I will also call attention to the fact, that in estimating the deflection of the Londonderry Bridge, I have treated the point of support as a fixed point, which is the case if all the spans are equally loaded; but in the event of one span being loaded and the adjoining span unloaded, the point of suspension will not be a fixed point, and the deflection will be greater than I have estimated.

Thus with one span loaded and the second span unloaded, the girder bridge

will show a comparatively better result than with the entire bridge loaded, but not to any sensible amount, as the same property which renders the suspended girder rigid will prevent the movement of the point of suspension.

The weight on one opening will create a disposition to straighten the chain in the adjoining opening, which will be resisted by the girder so effectually from being united with it, that little motion of the point of suspension will occur, even if no assistance were given by the tower.

We may make a similar comparison deduced from other large girders, of which the next largest actually erected is the Boyne Viaduct: here the

Span is	264 feet.
Weight of effective metal	300 tons.

To find a girder of equal depth and rigidity of 440 feet span, we have as—

$264^3 : 440^3 :: 300 : 1388$ tons; the weight of a girder being continuous that would deflect 1·9 inch with 540 tons all over, or about two-thirds of the rigidity of the Londonderry Bridge.

The Boyne Viaduct thus indicates a much more favourable result than the tube; and, as the system would admit of greater depth, much less metal would suffice for this span.

A similar deduction may be made from the Newark Dyke Bridge, which has—

Span of opening	240 feet.
Weight of metal	$244\frac{1}{2}$ tons.

Here we have as—

$240^3 : 440^3 :: 244\frac{1}{2} : 1506$ tons, the weight required to construct a girder that will deflect $2\frac{3}{4}$ inches with 240 tons, and indicates also a more favourable result than the solid-sided girder, but not equal to the Boyne Viaduct.

I must not conclude these comparisons without referring to Mr. Brunel's new system of combining an arch and a suspension chain, giving each half the duty.

There is no doubt, in the case of the proposed Londonderry Bridge, if the chain was reduced to half the section, and an arch of the depth of the chain was substituted, and the suspension rods extended to the arch, that theoretically with the same metal there would be equal strength and rigidity; but the real difficulty is the impracticability of such a construction: the metal in an arch of 451 feet span and 80 feet rise cannot be measured by the section as in a chain, from the tendency to buckle, and from having to contend with its own weight.

Thus in the Saltash Bridge, which is now in course of construction on this principle of 451 feet span, the depth is only 56 feet, or little more than $\frac{1}{3}$rd of the Londonderry Bridge if of that construction, and thus nearly three times the metal is required to give equal strength, and nearly nine times to give equal rigidity, from the deflection varying as the cube of the depth.

It will be observed that there will be no difficulty in giving even a greater depth to a suspension bridge; the vertical pressure or weight of the bridge is small compared with the pressure on the arch of Mr. Brunel's girder, and as the height is only 88 feet no practical difficulty arises.

Concluding Observations.

The important practical results of the preceding experiments are:—

1st. That in suspension bridges it is essential that the platform should be stiffened with a girder to prevent vertical undulation.

2nd. That the deflection of the wave of a girder attached to a chain similar

to the Londonderry Bridge, will not exceed $\frac{1}{25}$th of the deflection of the same girder not attached to the chain.

3rd. That theoretically the saving of metal to give equal strength in a suspension bridge is only one-half of that of a girder; but as it can be made of great depth without practical difficulty, and as the deflection varies as the cube of the depth, a bridge on this principle of such span as the Londonderry Bridge may be made under average circumstances with at least one-fourth of the metal of an ordinary girder bridge having equal rigidity.

The results Nos. 1 and 2, although at variance with the general practice of engineers, are still in accordance with such experience as we possess.

Suspension bridges, with a few exceptions, have been not only built of small depth without stiffening girders, either vertically or horizontally, but the points of suspension have not been fixed, but simply resting on rollers, so as to give every facility for movement; and thus arises the motion generally complained of in suspension bridges.

Moreover, suspension bridges have been built without any rule or supervision, and as they will bear their own weight, however lightly constructed, they have been in most cases of insufficient strength, many now existing not having $\frac{1}{6}$th or $\frac{1}{8}$th the strength given in the Derry Bridge.

In a few cases where a girder has been used, the results accord with my experiments. The Niagara Bridge of 820 feet span has a girder very little deeper than the Derry Bridge, and is built of timber only; yet the deflection from a train is not more than 5 inches, as appears from the Report of Mr. Roebling; an amount much less than my experiments would indicate, when it is considered that the girder is of timber only.

Another case is that of the Inverness Bridge, which has a wrought-iron parapet 3 feet 6 inches deep, and is nearly represented by the small wrought-iron model.

This bridge has been subjected to the test of a locomotive passing over it on a truck drawn by fourteen horses, which produced so little deflection, as appears from the Report of Mr. Rendel, that a member of the Institution of Civil Engineers, when the subject was mentioned at the recent discussion, expressed his doubt of the fact.

It is however satisfactorily explained by the preceding experiments, which prove that such a parapet is sufficient to render a suspension bridge so nearly rigid that no deflection would be observable without measurement.

There are other cases of suspension girder bridges, viz. the Montrose Bridge in Scotland, the Kief Bridge in Russia, and more recently the Chelsea Bridge over the Thames at London, in all of which it is reported that objectionable movement is cured; and I am informed by Mr. Vignoles, the engineer, that the Kief Bridge has been passed over by Russian artillery at a gallop without any objectionable oscillation or deflection. In America suspension bridges have been used for aqueducts, the trough acting as a girder, the success of which proves that all vertical and horizontal oscillation has been cured.

I will conclude my paper by remarking, that it has been necessary in the preceding investigation to make reference to the existing works of eminent engineers. I am desirous to observe that such comparisons have been essential to the elucidation of the question, and that I have no intention for one moment to detract from the engineering merit of these great works. The genius exhibited in overcoming the various difficulties which presented themselves during their execution must be evident to all, but especially to those whose profession renders them acquainted with what had to be contended with.

At the time they were designed, the popular objections to suspension bridges were much greater than at present, and no example existed of a railway suspension bridge.

An engineer might then have been as little justified under such circumstances in adopting a suspension bridge for railway traffic, as he would now be in error in disregarding the experience which has since been obtained.

It is still, however, asserted, but without any assigned reason, that suspension bridges are not adapted for trains at speed; my own view on this point, from large experience in railway construction, from observing the effect produced on bridges crossed by contractors' waggons drawn by horses, and by experiments made on trains at speed with the Iron Commissioners, is, that road traffic gives as severe trial by troops marching in step, by herds of cattle, or by cavalry trotting or galloping, as the heaviest trains at full speed on railways.

This is not, however, the subject I now submit for discussion; the first step in the inquiry is the simple mechanical problem of the strength and deflection with stationary loads, on which no doubt should exist; and when it is remembered that the extension of the railway system is much governed by the cost of construction, of which the crossing of valleys and rivers forms so considerable an item, that in some cases a single bridge costs as much as 75 or 100 miles of line, I hope the inquiry will be deemed of sufficient importance by the Association to elicit a full investigation and discussion.

APPENDIX.

A.

Estimate of Deflection of the Londonderry Girder, from experiments on the Boyne Viaduct.

The centre opening is 264 feet. Weight of girder 300 tons. 540 tons all over produces a deflection of 1·9 inch.

The deflection, if of the length of the Londonderry Bridge, would have been $264^3 : 440^3 :: 1{\cdot}9 : 8{\cdot}79$ inches.

To ascertain the deflection, if of the same depth as the Londonderry Bridge, we have $16{\cdot}5^3 : 22{\cdot}5^3 :: 8{\cdot}79 : 22{\cdot}289$ inches.

This assumes a weight per foot forward equal to the Boyne Viaduct. The Boyne Viaduct, if of the same length as the Londonderry Bridge, would weigh 512 tons.

The following will therefore be the deflection, if of the same weight as the Derry Bridge:—150 : 512 :: 22·289 : 76·078 inches, which is the deflection with 540 tons all over. 200 tons all over will therefore be 28·17; 100 tons in the middle, 23·53 inches.

Estimate of the Deflection from Experiments on the Newark Dyke Bridge.

Span, 240 feet; weight of girder, $244\frac{1}{2}$ tons; deflection with 240 tons all over, 2·75 inches. As $240^3 : 440^3 :: 2{\cdot}75 : 17$ inches.

The depth of the Newark Dyke being the same as the proposed Londonderry Bridge, 17 inches will indicate the deflection, if it was equal in weight to the Newark Dyke Bridge; but the weight, if of the same length, being 450 tons, we have,—150 : 450 :: 17 : 51 inches, the deflection with 240 tons all over. With 200 tons all over, 42·5 inches.

With 100 tons in the middle it will therefore be 34 inches.

Estimate of the Deflection from Experiments on the Britannia Tube.

The Britannia Tube weighs 1600 tons, and deflects with 200 tons all over 1·25 inch.

The deflection of the Britannia Tube, if reduced to 150 tons, would be 12·5 inches.

The depth, practically, of the proposed Londonderry Bridge is $16\frac{1}{2}$ feet, and of the Britannia Tube 28 feet,—$16^3 : 28^3 :: 12·5$, or $449·21 : 2195·20 :: 12·5 : 6·07$ inches, which has to be reduced in the ratio of the cube of the span, $460^3 : 440^3 :: 60·7 : 53·08$ inches, the deflection of the Londonderry girder with 200 tons all over.

The mean of the three results indicates 41·25 inches as the deflection of a girder of 150 tons, loaded all over with 200 tons, and 33 inches when loaded in the middle with 100 tons: $\frac{33}{25}=1·32$ will therefore be the deflection when attached to the chain *.

B.

Dimensions of Londonderry Bridge, and calculation of Strains and Deflection.

Span between points of support, 451 feet; length of the girder, 440 feet; depth at high tower, 88 feet; depth at side tower, 59 feet; centre catenary half horizontal length, 246 feet; side catenary, half horizontal length, 205 feet; length, half chain (centre), 266·2 feet; length, half chain (side), 215·5 feet.

Strain on cables at high tower with 3 tons per foot load, assuming $\frac{1}{6}$th to be supported by the girder and $2\frac{1}{2}$ tons by the chain, according to the formula

$$T=\frac{w}{4x}\sqrt{4x^2+y^2}=\frac{1200}{4788}\times\sqrt{4\times 88^2+246^2}=1031 \text{ tons},$$

x being the depth of catenary, y the half span, w the weight equally distributed, and T the tension.

Section of the cable at high tower, so that no strain exceeds 5 tons per inch, 206 inches.

Strain of the cable at the side tower,

$$\frac{1000}{4\times 59}\times\sqrt{4\times 59^2+205^2}=1000 \text{ tons}.$$

Section of cable at side tower, 200 inches; horizontal strain, 840 tons; section of iron at bottom of chain, 168 inches.

Deflection from Expansion and Contraction.

This calculation assumes that the expansion between summer and winter is $\frac{1}{2000}$th part of the length, and that it produces a strain of 5 tons per inch. The exact length of the chain from the formula

$$z=\sqrt{y^2+\tfrac{4}{3}x^2} \text{ or } \sqrt{246^2+\tfrac{4}{3}88^2}=266·16,$$

z being half length of catenary,
y being half chord,
x being versed sine.

Add elongation of half the cable	·133
	266·293

$$x=\sqrt{\tfrac{3}{4}z^2-y^2}=\sqrt{\tfrac{3}{4}266·293^2-246^2}=88·3.$$

The deflection, therefore, from the temperature will be $\frac{1}{3}$rd of a foot, or 4 inches, a deflection much under that of ordinary suspension bridges, arising

* The deflections are here estimated to vary as the cube of the depth, in order to obtain the extreme amount. The more correct result in a beam of this form will be from the square, so that the means here given of 41·25 and 33 inches will considerably exceed the actual deflection.

from the great depth. From this has to be deducted the expansion of the cast-iron towers, which will amount to $\frac{1}{2}$ an inch.

The same deflection of course indicates the effect of 3 tons per foot on the bridge, as this weight produces 5 tons per inch strain on the cable. One foot per ton all over will therefore cause a deflection under $1\frac{1}{2}$ inch.

C.

In the design for the proposed Londonderry Bridge, ornamental cast-iron towers are proposed. As a mechanical question, we must estimate them as cast-iron columns acting simply to carry weight, which, if they were so designed, would be as follows:—

The weight to be supported by the high tower when the bridge has its extreme load, is 1500 tons. To give 4 tons per inch, we require 375 inches, or 3750 lbs. per yard.

The high towers being 30 yards high, the weight of metal will be 50 tons.

The low tower will have 1320 tons with a full load, $\frac{1320}{4}=330$ inches, or 3300 lbs. per yard; the height being 20 yards, the weight will be 20 tons.

The mean of the two towers will require for direct strain 40 tons. Add 50 per cent. for bolts and ineffective material, 20 tons$=$60 tons.

D.

Estimate of the Weight of Suspension Bars.

The weight to be carried is 1100 tons, if we allow 5 tons per inch; the section required is 220 inches, or 2200 lbs. per yard; the average length is 10 yards, and weight 10 tons. Add 50 per cent. for ineffective metal 5 tons $=$15 tons.

Evidences of Lunar Influence on Temperature. By J. Park Harrison, *M.A.*

[A Communication addressed to Major-General Sabine, General Secretary to the British Association, and ordered to be printed among the Reports.]

A fall in temperature having been found to recur with some frequency between ● and ☽, and a corresponding rise shortly after ☽, tables and curves were formed in the early part of 1857, for a series of lunations, and a careful comparison instituted between the temperatures of the days at the period of suspected action. The result of the inquiry was satisfactory. It appeared beyond question that decided effects (depending on lunar influence) occurred at the time referred to; and even that a single day—the third before ☽,—was on the annual mean of considerably lower temperature than another day, viz. the second after ☽; the difference between the two temperatures being by far the greatest in the winter months. These facts I had the pleasure of communicating to you soon after they had been ascertained; and they were shortly afterwards laid before the British Association at Dublin.

The following Table was then formed of the mean annual temperatures of eight fixed days, viz. the third before and the second after the four principal phases of the moon in each lunation, for 21 years. The observations chiefly used were those made at Dublin under the direction of the Ordnance Survey in 1836–1852, and were well adapted to my purpose from being collected in a single volume; the remainder were from the Greenwich results of 1852–1857.

TABLE I—Mean Annual Temperatures of certain fixed days in the Lunations of 1836–1857.

Years.	3 D.	●	2 D.	3 D.	☽	2 D.	3 D.	○	2 D.	3 D.	☾	2 D.	3 D.
At Dublin.													
1836, 1837....	47·6	*	47·8	46·4		48·1	48·5	*	45·9	47·5		49·4	47·6
1837, 1838....	47·7	*	47·8	47·1		48·0	49·1	*	47·7	46·6		47·5	47·7
1838, 1839....	49·3		46·3	46·7		47·6	47·5		48·1	46·7		45·9	49·3
1839, 1840....	47·0	*	49·0	48·4		49·6	49·5	*	47·1	48·1		46·5	47·0
1840, 1841....	48·8		47·1	49·0	*	48·5	46·0		46·1	46·4	*	48·2	48·8
1841, 1842....	47·6		48·0	47·3		49·7	47·6		49·3	50·2		47·6	47·6
1842, 1843....	49·0		48·9	47·5		47·6	47·6		48·8	48·6		50·2	49·0
1843, 1844....	48·5		47·5	49·0		49·4	48·4		46·5	49·0		48·2	48·5
1844, 1845....	48·2		47·1	45·8		48·8	46·0		50·0	48·6		47·6	48·2
1845, 1846....	51·0		49·1	49·3		50·7	49·2		51·5	48·9		49·7	51·0
1846, 1847....	46·0		50·0	46·7		47·5	46·9		48·2	50·8		46·4	46·0
1847, 1848....	48·6		49·9	48·1		49·4	46·7		48·8	49·0		47·3	48·6
1848, 1849....	47·6		45·5	46·8		49·4	48·6		49·7	49·7		46·8	47·6
1849, 1850....	47·9	*	48·5	48·2		48·5	49·5	*	46·4	49·0		49·2	47·9
1850, 1851....	49·9		49·4	47·3		49·0	48·0		49·9	49·2		48·4	49·9
1851, 1852....	50·3		48·6	46·3		48·4	48·6		48·5	49·1		50·0	50·3
At Greenwich.													
1852, 1853....	51·0		50·6	49·1		50·3	47·0		47·9	50·6		49·6	51·0
1853, 1854. .	49·0		48·2	48·3		50·0	46·5		47·3	48·1		49·0	49·0
1854, 1855....	45·6		44·8	44·3		49·6	47·8		48·8	49·1		47·6	45·6
1855, 1856....	49·1	*	49·9	46·6		50·0	48·7	*	48·4	50·9		50·1	49·1
1856, 1857....	51·4		48·6	51·7	*	49·0	51·8		48·6	47·9	*	53·0	51·4
Means....	48·6		48·2	47·6		49·1	48·1		48·2	48·1		48·3	48·6

From this Table it will be seen,—

At the period of { ● / ○ } there was { a fall / a rise } in thirteen years out of twenty-one.

And in five of the eight years in which there are exceptions to the (assumed) rule of a higher temperature preceding ●, exceptions are also found at the period of ○.

And so with the quarters:—

At the period of ☽ there was a rise in nineteen years out of twenty-one.
At the period of ☾ there was a fall in thirteen years out of twenty-one.

Only two exceptions occurred at ☽, and in both cases they are found in the same years at ☾.

2. Winter lunations to all appearance exercising a considerable influence upon the mean temperature of the two days at the period of ☽, inquiry was next extended to individual months. The results evidence the same marks of system that have been already observed in the yearly means.

In the months of October, November, December, and January, the proportion in which a rise or fall occurred from the third day before to the second day after the syzygies and quarters, during the same twenty-one years, was as follows:—

In October, .. at	●	a rise in 13 out of 21.
	○	a fall in 15 out of 22.
In November, at	●	a fall in 16 out of 23.
	○	a fall in 13 out of 22.
In December, at	●	the rise and fall equal.
	○	a rise in 14 out of 22.
In January, .. at	●	a fall in 17 out of 22.
	○	a rise in 16 out of 21.
In October, .. at	☽	the rise and fall equal.
	☾	a fall in 16 out of 21.
In November, at	☽	a rise in 14 out of 21.
	☾	a fall in 13 out of 20.
In December, at	☽	a rise in 13 out of 21.
	☾	the rise and fall equal.
In January, .. at	☽	a rise in 16 out of 21.
	☾	a fall in 13 out of 23.

In the summer months a rise prevailed in the proportion of about 3 : 2, at all the periods, excepting in May, at the time of ☽, when it was as 4 : 1.

At the period of ☾, there occurred in the same 21 years the following remarkable alternations of temperature:—

In March, .. a rise in 12 out of 21.
In April, .. a fall in 13 out of 21.
In May, .. a rise in 13 out of 21.
In June, .. a fall in 13 out of 21.
In July, .. a rise in 13 out of 21.
In August, a fall in 13 out of 21.

Strong indications of similar reciprocity were traceable in separate lunations and at different periods of the same lunations.

3. Further evidence of system was next obtained from the highest and lowest mean temperatures of each month. These were found in a tabular

form, with the dates attached, for 22 years, in the results of the Dublin Observations. And although it was scarcely to be expected that monthly maxima and minima would coincide to any extent with the annual mean temperatures (or means of the means) of the eight days at the different lunar periods, in the *first* half of the lunation they appeared in a great measure to do so.

At the periods of the syzygies and quarters, upon the days of the change, and for the three days before and after, the proportion in which maxima and minima mean temperatures occurred in each month, is shown approximately in the following Table; the signs + and — before the figures indicating the predominance of maxima or minima:—

TABLE II.

Months.	●	☽	○	☾
November	+ 5 : 4	+ 2 : 1	=	− 2 : 1
December	+ 3 : 2	=	− 3 : 2	− 5 : 4
January	+ 2 : 1	+ 2 : 1	− 3 : 2	− 2 : 1
February	+ 3 : 2	+ 3 : 2	− 3 : 2	=
March	+ 2 : 1	− 2 : 1	− 2 : 1	− 3 : 2
April	+ 5 : 4	− 3 : 2	+ 5 : 4	+ 3 : 2
May	− 3 : 2	+ 3 : 2	− 3 : 2	+ 3 : 2
June..................	− 5 : 4	− 5 : 4	− 3 : 1	+ 2 : 1
July	− 3 : 2	+ 2 : 1	+ 5 : 4	− 3 : 2
August...............	− 3 : 2	− 5 : 4	+ 3 : 2	=
September	− 3 : 2	=	− 3 : 2	+ 2 : 1
October	− 2 : 1	+ 3 : 2	+ 3 : 2	− 2 : 1

Thus, in winter, for six consecutive months, maxima predominate at ●; for the other six months minima, and that in much the same proportion. In four of the winter months, viz. December, January, February, and March, in which maxima preponderate at the period of ●, minima are in excess at ○. In July, August, and October, the converse holds good. At the quarters, a similar reciprocal action takes place in the months of October, November, January, April, June, and July.

4. Not the least striking fact which has been elicited during the progress of this investigation, is the systematically unequal distribution of the maxima and minima mean temperatures over the several days of the lunation. At Dublin, for the period under consideration, the greatest number of high and low temperatures at each quarter, excepting at ○, occur upon the day following the change. In the annexed Table this will be clearly seen, as well as an apparent increase in the numbers as they approach the four days of greatest action—more particularly at the quarters.

TABLE III.—Showing the distribution of the 530 maxima and minima mean temperatures of day in each month for 22 years at Dublin.

⅛				●				⅛				☽				⅛				○				⅛				☾			
6	23	9	8	21	24	15	23	7	11	14	15	18	21	13	8	8	15	15	27	26	24	12	18	9	15	18	19	25	26	20	16

The other points to which I wish to direct attention in this Table are the excess of maxima and minima upon the third day before and third day after ●, and the regular progression of effects at the octants.

At ☽, out of the 13 maxima and minima, on the second day after the day of change, the proportion of the former to the latter was as 2 : 1. No maxima or minima, however, were found to occur for 22 years on any of the three days following on ☽ in the months of April, May, June, July, September, or October; whilst on the 4th day after ☽ (or the 2nd octant), seven out of the eight maxima and minima occurred in these very months.

At ☾ there is the following alternation,—

☾.

+12 −12 +14 −20 −15.
− 6 + 7 −11 + 6 + 5.

5. By the courtesy of Mr. Glaisher I am able to give additional evidence of system of considerable value from his tables of mean temperatures of each day at Greenwich for 43 years.

It will be interesting to compare the maxima and minima mean temperatures, which I have extracted for the earlier half of this period (from 1814 to 1835), with the Dublin results (from 1830 to 1852). Thus the number of maxima and minima of the month which occurred at Dublin on the three days preceding ● were, +13−10; +3−6; +5−3. At Greenwich +11−6; +3−6; +8−7. On the three days before ☽, at Dublin, +6−5; +6−8; +7−8. At Greenwich, +8−7; +9−11; +8 −9. On the first and second days after ☽, at Dublin, +12−9; +9−4. At Greenwich, +8−6; +15−6. On the three days before ○, at Dublin, +8−7; +6−9; +15−12. At Greenwich, +15−10; +10−8; +5−6. On the second day before and after ☾, at Dublin, +13−5; +4−16. At Greenwich, +10−9; +8−20. The due proportion of maxima and minima would have been +9−9 *for each of the above days*. This, in the following Table of maxima and minima in the month for the days of the change, will be found to be very nearly the case at ● and ☽.

TABLE IV.

	●		☽		○		☾	
At Dublin, 1830–1852.	21	+11. −10.	18	+ 8. −10.	26	+10. −16.	24	+13. −11.
At Greenwich, 1814–1836,...	20	+10. −10.	18	+ 9. − 9.	23	+15 − 8.	23	+14. − 9.

It will be noticed also, that with the single exception of the day of ○, the regularity in the proportion of maxima to minima which runs through these figures is far greater than could *a priori* have been thought possible.

6. Though time has not permitted me to enter on an examination of the remaining mean temperatures at Greenwich, I am able to give the highest and lowest maxima and minima in the month for the whole series of 43 years from the notes at the foot of Mr. Glaisher's Tables; the days of the moon's age being obtained from the Nautical Almanack. The following was found to be the grouping of the highest and lowest temperatures at the period of ☽, to which attention was originally drawn:—

☽

− − − + · − −
− − + +
+

That is to say, on nearly 16,000 observations, eleven out of the twenty-four highest and lowest mean temperatures occurred at the above period, and

minima only before the day of change. The just expectation would be about 3 maxima and 3 minima for the whole period of seven days.

The results at Dublin for twenty-two years were at—

$$\begin{array}{ccccccc} & & & \text{☽}. & & & \\ \cdot & - & \cdot & + & + & + & \cdot \\ & - & & & - & & \end{array}$$

In this case also minima precede the day of the change.

For the rest more than half of the whole number of the superior maxima and minima occurred on the following eight days, both at Greenwich and Dublin, viz the third day before, and the third day after ● ; the second day before, and the second day after ☽ ; the day before ☾ ; and the days on which the moon entered on her first, second, and third quarters.

Of the six days of the lunation on which no superior maxima or minima occurred, either at Greenwich or Dublin, three were found at ●, two at ○, and one at ☾.

Many other details of interest might be enumerated; but when it was considered that the observations on which they depend are ordinary daily means, taken irrespective of the hour of the moon's changes, it seemed hardly worth while to dwell on minute points which would at present only complicate the question.

7. The dissolution of clouds in presence of ○, first announced as a meteorological fact by Sir John Herschel, has since been confirmed by observations made by Mr. Piazzi Smyth on the Peak of Teneriffe, at which altitude sufficient heat was detected in the lunar rays to make it possible that evaporation might cause the phænomenon in still higher regions of the air. It had been noticed previously, and independently, by Baron Humboldt in America.

A still more remarkable fact has been noticed by Mr. M. J. Johnson, the Radcliffe Observer at Oxford, viz. that the cloud-dispelling power of the moon extends beyond the period of ○ ; or as it would perhaps be more correct for me to say, is not confined to it. From repeated observations it appears that at Oxford the influence begins after the moon is four or five days old, and lasts till she approaches the sun again the same distance on the other side. So frequently had this been noticed by Mr. Johnson, that during a course of observations on which he was engaged a few years ago, he felt that his attendance at the observatory could not be dispensed with, however unpromising might be the appearance of the night, until the moon had fairly risen; and over and over again when this has occurred, the sky, before completely obscured, has become clear.

Mr. Johnson has furnished me with a comparative statement of the number of observations of the sun and moon taken beween the day of ☽ and the day after ○, in the years 1844, 1845, and 1846, which shows that the moon was visible on an average 137 times on the meridian, while the sun is seen only 100 times. In the year 1844 the preponderance in favour of the visibility of the moon was as 1·52 : 1.

A clearing of the atmosphere, to whatever attributable, by increasing solar as well as terrestrial radiation, and so producing extremes of heat and cold, would, it is evident, be sufficient to account for some of the results enumerated in this communication.

The importance of Mr. Johnson's facts, in connexion with the peculiar action which it has been shown exists at the period of ☽, will be at once apparent; and however little required, the latter in a measure strengthens the probability that the effects which have been observed are not accidental.

8. Before concluding, it will be necessary to explain the mode in which my results were obtained.

The average length of a lunation being a little more than $29\frac{1}{2}$ days, and the difference between the quarters varying from three or four hours to two days and even more, with a view to secure as much uniformity as the circumstances of the case, in the absence of a sufficient number of hourly observations, would admit, the mean temperatures of the days on which the moon entered on her four principal phases were first set down as centres, and then the mean temperatures of the days immediately before and after them, each in its proper order; and so with the maxima and minima of the month.

By this method it will be seen that the numerically imperfect observations in each quarter fell upon the intermediate or octant days; and my results, I think, show that this was a proper method to adopt. Otherwise, and if there had been any indications of a regular progression of effects from ● to ○, it would have been better to take the latter as a centre, and to have arranged the observations accordingly.

The investigation is now being carried out further by means of the highest and lowest readings of the self-registering maximum and minimum thermometer.

Garlands, Ewhurst, Surrey.

P.S. Dr. Buys Ballot, Director of the Royal Meteorological Institute of the Netherlands, informs me that he has found the highest temperature to follow on ○, which he attributes to the greater amount of heat reflected from the moon's surface at that period. M. Ballot's results are formed from observations made at Haarlem, extending over 120 years. The effects were there too most conspicuous in the winter months.

Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 *to* 1855 (*inclusive*).

In consequence of a suggestion from Professor Balfour at the Glasgow Meeting 1855, it was considered a very desirable object to obtain some information relative to the species of animals and vegetables which furnish the articles of commerce, and the extent to which the demand on each is carried. The General Committee therefore recommended as an experiment, that Committees should be appointed for this purpose in Liverpool and Glasgow to collect the necessary particulars and report thereon. The gentlemen chosen for Liverpool were Professor T. C. Archer, Queen's College, Liverpool, and Joseph Dickenson, M.D., F.R.S., F.L.S., &c.

Unfortunately the serious indisposition of Dr. Dickenson obliging him to travel, he was unable to take any active part in preparing the following Report, to which his great experience would have been so valuable; but as it was seen that the sum voted by the General Committee would be insufficient to meet the expenses of clerical assistance, Dr. Dickenson liberally undertook to pay any excess of expenditure, thus giving valuable aid to its completion.

The plan pursued in obtaining the results was as follows:—

In each large port there is published daily, a paper called "The Bill of Entry," which gives, besides a variety of other particulars, the arrival of

every vessel, the port from whence she sailed, and a copy of her manifesto, giving an account of the cargo she brings. By the kind cooperation of Mr. Robert MacAndrew, a complete file of these papers for the five years was obtained, and, books being prepared for the purpose, a clerk was employed to go over the file and transcribe every importation under its proper heading, and to make inquiries of the merchants or brokers whenever it was doubtfully expressed, as was very frequently the case. One thousand five hundred and sixty-five of these mercantile newspapers were thus collated, and every package imported in the five years was recorded. The next step was to ascertain the average weight of each package, or the entire weight of each consignment, which was done chiefly by personal application to the consignees, who in every instance, when applied to and informed of the cause of inquiry, readily gave the required information.

It cannot be doubted that the connexion of Science and Commerce in this practical way, if followed out, will have a most important effect upon human progress. The man of science, by learning the particular species which afford valuable products, will by his knowledge of affinities be enabled to direct the merchant to new fields of enterprise; and when science thus shows its power of being practically useful, the respect for it will be increased, which must greatly assist in its advancement.

But the method pursued in the present instance is too laborious and too partial to be of any great use, except as indicating the important information which is lost to the country for want of a more complete system of statistics. The Board of Trade "Returns" would appear to supply the deficiency to a great extent; but a comparison of the following tables with that voluminous production will show that very many things are never mentioned in the Official Returns, except under such general denominations as "Drugs not otherwise enumerated," &c. Now it is to the unknown articles that most attention should be given: intelligent people abroad see natural productions which they believe would be most useful to our manufactures, or in our *Materia Medica*; they send a small quantity for experiment, which being unknown, is entered under some general term similar to the above, and the Revenue is satisfied. The broker, if a man of extensive business, does not like to be troubled with small matters; and the article is laid aside until valueless, and then consigned to the dust-cart. In this way the importation of the valuable Hydroborate of Soda, now extensively imported as borax from South America, was in abeyance for at least six years; and almost numberless instances of a similar kind might be collected in our largest sea-ports.

The remedy for this would be the appointment of an official in the landing department of each port, to ascertain and record every new importation. The merchant in all such cases would willingly give a specimen for examination; and as there are now Industrial Museums in London (Kew), Liverpool, Edinburgh, and Dublin, the specimens could be determined there, and remain for public inspection. It ought also to be imperative upon the Landing Officers to return every importation by its correct name, a difficulty which would be very trifling if either of the above Museums were referred to. One other reason cannot be objected to:—if National Statistics are worth collecting, they can only be so when correct; and correct statistics must be more essential to a great commercial nation than to any other.

T. C. Archer.

Tables.

2nd Division INVERTEBRATA.

Class Protozoa.

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Spongiæ.	Sponge (Turkey) .... *Spongia officinalis*, Linn.	The peculiar skeleton, whole.	Southern & Eastern seas.	Turkey.........	cases. 95	cases. 175	cases. 110	cases. 163	cases. 146	The cases contain about 500 sponges of various sizes. Av. value: 35*s*. per lb.
	Sponge (W. Indian or Bahama) .... *Spongia* (sp.?).	The skeleton ...	W. Indies.........	Bahama Islds.						

Class Radiaria.

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Anthozoa.	Coral .... *Corallium rubrum*, Lam.	The axis of the polypidom.	Tropical & Temperate seas.	Italy...............	....	120 lbs.	....	146 lbs.		

Class Insecta.

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Order 7th. Hemiptera.	Cochineal........................ *Coccus cacti*, Linn.	The whole insect	Mexico...........	S. America	133 cwt.	191 cwt.	146 cwt.	187 cwt.	173 cwt.	For dyeing only.
	Lac .... *Coccus lacca*, Kerr.	The resinous secretion or exudation, and the colouring matter of the body. The former as	E. Indies	Bombay.						
		Shell-lac ...... Stick-lac ...... Seed-lac	....	....	323 tons.	150 tons.	325 tons.	120 tons.	79 tons.	Used for making varnish.
		and the latter as Lac-dye ...... or Cake-lac ... and Lac-lake..	....	....	48 ,,	120 ,,	82 ,,	60 ,,	36 ,,	For dyeing only.

Order 1st. Coleoptera.	Indian Beetles. *Buprestis* (sp.?).	The wing cases or elytra.	India	Calcutta	....	....	....	....	....	A few of these beautiful elytra reach here as ornaments of Khus-khus baskets, fans, &c., and on muslins to enrich the embroidery. They have a brilliant metallic green colour.
	Spanish Fly. *Cantharis vesicatoria*, Lat.	The whole insect	Europe	Italy	....	2 cwt.	4 cwt.	....	3 cwt.	
Order 4th. Hymenoptera.	The Bee. *Apis mellifica* (Linn.)	The honey	Asia and Europe	Europe, Asia, & America; chiefly from Lisbon.	36 ,,	34 tons.	27 tons.	30 ,,	18 tons.	
		The wax	....	Europe, Asia, Africa, and America.	27 ,,	21 ,,	30 ,,	22 ,,	24 ,,	
Order 6th. Lepidoptera.	Silkworm, Common. *Bombyx mori* (L.).	The silk secretion as spun.	India	China and Bengal	lbs. 47,600	lbs. 42,800	lbs. 34,400	lbs. 57,800	lbs. 54,093	
		The gut, or silk unspun.			10	....	....	30		
	Silkworm (Tusseh). *Saturnia mylitta.*	The silk secretion as spun.	India	E. Indies	12,000	....	2,000	8,000	11,000	

Class Mollusca.

1st §. Cephalopoda.	The Cuttle-fish. *Sepia officinalis* (Linn.).	The shell, called Cuttle-bone.	....	....	....	....	....	....	12 cwt.	Used by druggists, chiefly for making tooth powders.
		The dried secretion of the Ink-bag.	....	China	....	....	....	....	....	A few pounds are annually imported, made into cakes, and known as Indian Ink.
2nd §. Conchifera.	The Pearl Oyster. *Meleagrina margaritifera* (Lam.).	The Shell	Tropical Seas	E. Indies, Panama, Manilla.	415 tons	480 tons	430 tons	550 tons	570 tons	
		The concretions of nacre, called Pearls.	....	East Indies	....	....	....	....	....	Pearls are frequently imported, but there is no record kept of the quantity.
	American Oyster. *Ostrea edulis? var.*	The animal alive.	....	United States	60 bush.	50 bush.	70 bush.	60 bush.	65 bush.	

INVERTEBRATA.—Class Mollusca (*continued*).

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
§ Gasteropoda.	The Conch Shell............... *Strombus gigas* (Linn.).	The shell.........	Shores of the W. Indies, &c.	The Bahamas ...	6,000 sh.	....	11,000sh.	....	....	These shells are imported in considerable quantities from time to time. They are used for making Cameos, and the refuse and inferior shells are said to be used in the potteries. Great numbers are also sold as ornaments.
	The Cowrie .... *Cypræa moneta* (Linn.)	The shell.........	....	....	1704 cwt.	2793 cwt.	1680 cwt.	90 cwt.	311 cwt.	There are two commercial varieties of the Cowry; one called the "*Live Cowry*," taken whilst the animal is alive in the shell, and "Dead Cowry." Both are exported to Africa, where they are used as money, and exchanged for Palm Oil, Ivory, Gum, &c.

1st Division VERTEBRATA.

Class Pisces.

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
3rd. subbrachiati.	The Cod .... *Gadus morrhua* (Linn.).	The whole fish...	Northern Seas...	Newfoundland...	257 tons	260 tons	293 tons	318 tons	450 tons	
		The sound or air-bladder salted.	....	....	15 cwt.	60 cwt.	27 cwt.	38 cwt.	13 cwt.	
		Oil of the liver Pitchings or dregs of the liver oil.	....	Newfoundland...	3200 tuns	1290 tuns	2300 tuns	2870 tuns	2460 tuns	

Order [...] Malacopterygii	Ling..................... *Gadus mollua*, Cuv.	The whole fish...	Northern Seas...	Newfoundland...	5 tons.	7 tons.	4 tons.	3½ tons.	8 tons.	
	Hake .... *Merluccius vulgaris* (Cuv.).	New York or Ribbon Isinglass. The air-bladder.	Northern Seas...	New York	....	6 cwt.				
Order 2nd. Malacopterygii abdominales.	The Salmon..................... *Salmo salar* (Linn.).	The whole fish (salted).	Northern Seas and Rivers.	Labrador, Newfoundland, Richibucto, New Brunswick, Canada.	73 tons.	84 tons.	67 tons.	78 tons.	86 tons.	
	The Herring .... *Clupea Harengus* (Linn.).	The whole fish, preserved.	Northern Seas...	Newfoundland...	5 „	3 „	7 „	4 „	3 „	These are foreign preserved Herrings, generally dried.
	The Anchovy .... *Clupea eucrassicholus* (Cuv.).	The whole fish, preserved.	Mediterranean...	Italy and France.	166 cwt.	115 cwt.	173 cwt.	122 cwt.	139 cwt.	
	The Pilchard .... *Clupea pilchardus* (Linn.).	The whole fish, preserved.	Mediterranean...	Marseilles	....	12 „				
	The Sardine..................... *Clupea sardina* (Cuv.).	The whole fish, preserved in oil.	Mediterranean...	France	65 „	73 „	80 „	88 „	87 „	
	The Shad..................... *Alosa vulgaris* (Cuv.).	The whole fish...	Northern Seas...	New Brunswick..	....	5 „	2 „			
Order 1st. Acanthopterygii.	The Mackerel .... *Scomber scombrus* (Linn.).	The fish, preserved.	Temperate and Arctic Seas.	Richibucto, Canada, &c.	2 tons.	6 tons.	4 tons.	7 tons.	6 tons.	

VERTEBRATA.—Class Pisces (*continued*).

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Chondropterygii Branchiis liberis.	The Sturgeon .... *Acipenser sturio* (Linn.).	Isinglass, or the air-bladder dried.	Northern Rivers.	Canada, Russia	483 cwt.	416 cwt.	497 cwt.	520 cwt.	570 cwt.	
	Supposed to be derived from the genera Pimelodus and Silurus. (Order Malacophrygii abdominales.)	Brazilian Isinglass.	The rivers of Brazil.	Para, Maranham, Paraiba						
Class Reptilia.										
Order 4th. Testudinata.	Turtle (alive) .... *Chelonia mydas* (Brongn.).	The flesh	Tropical Seas ...	Chiefly from the W. Indies.	352	416	376	312	518	
	The Hawk's-bill Turtle ...... *Chelonia imbricata* (Brongn.).	The carapace, called Tortoise-shell.	Southern and Tropical Seas..	E. & W. Indies, Africa and S. America.	40 lbs.	60 lbs.	8 lbs.	50 lbs.	80 lbs.	Considerable quantities are imported in a manufactured state from India.
	Snapping Turtle .... *Testudo ferox* (Gm.).	The flesh	The American Rivers.	United States ...	....	120	100	50	130	Used only as food, considered superior to the Green Turtle.
Class Aves.										
Order 3rd. Gallinaceæ.	The Domestic Fowl ...... *Gallus Bankiva* (Temm.).	The eggs	....	Alexandria ... St. Michael's..	50 cases 10 cases					
		The albumen of the egg dried.	Domesticated in all parts of the globe.	France	30 lbs.	....	....	....	....	Use unknown. Only one importation.
	The Peacock .... *Pavo cristatus* (Linn.).	The so-called tail feathers.	E. Indies	E. Indies	....	....	....	....	....	Only imported made up into fans, fly-whisks, and other small ornamental objects.

Order 4th. Grallatoriæ.	The Ostrich.................... *Struthio camelus* (Linn.).	The feathers ...	Africa	....	....	feathers. 2,600	feathers. 1,270	....	feathers. 3,000	
Order 5th. Natatores.	Penguin .... *Aptenodytes patagonica* (Gm.).	The skin of the neck.	Straits of Magellan, New Guinea, &c.	Singapore	60 doz.					
	Species various.	Guano, the dried fæces and exuviæ	....	Bolivia, Ichaboe, Patagonia, &c.	tons. 50,245	tons. 63,376	tons. 47,633	tons. 54,860	tons. 64,677	Used only for manure.
				Class Mammalia.						
Order 11th. Marsupiata.	The Kangaroo................ *Macropus major* (Shaw).	The skin	Australia	Australia	....	....	skins. 200	skins. 60	skins. 150	Much sought after for making boot-tops; they are usually imported as presents.
Order 10th. Rodentia.	Chinchilla .... *Chinchilla lanigera* (Geoff. & Desm.).	The fur...........	Chili..............	Valparaiso, Lima, and Arica.	dozens. 100	dozens. 80	dozens. 140	dozens. 170	dozens. 60	Two kinds are imported; one, called Bastard Chinchilla, is inferior to the other.
	Squirrel (Grey) .... *Sciurus cinereus* (Linn.).	The fur...........	Canada...........	Canada...........	80	67	156	200	88	
	Musquash .... *Fiber zibethicus* (Cuv.).	The skins and fur	America	Buenos Ayres ...	56	....	....	20	80	
	Beaver......................... *Castor fiber* (Buff.).	The preputial follicles.	N. America	Canada...........	....	10 lbs.	....	....	....	Used only in pharmacy.
	Porcupine .... *Hystrix cristata* (Linn.).	The quills	Barbary and S. of Europe.	Sicily	....	3,000	....	12,000	8,000	Used chiefly for penholders.

VERTEBRATA.—Class Mammalia (*continued*).

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Order 10th. Rodentia.	The Urson .... *Hystrix dorsata* (Linn.).	The quills	N. America	Canada...........	....	....	....	....	....	These quills never reach us as regular importations, but great numbers dyed by the Indians and used to embroider mocasins and bark-work are constantly arriving as curiosities.
	The Ox .... *Bos taurus* (Linn.).	The hide	....	S. America and Europe.	hides. 759,995	hides. 604,386	hides. 715,053	hides. 492,449	hides. 568,367	
		The hair	....	S. America	7 tons.	10 tons.	....	4 tons.	6 tons.	
		The horns	....	S. America	horns. 813,900	horns. 762,000	horns. 940,000	horns. 812,600	horns. 520,000	
		The hoofs	....	S. America	tons. 160	tons. 178	tons. 143	tons. 163	tons. 127	
		The flesh salted..	....	N. America and Europe.	5560	6869	4800	5760	5800	
		The bones	....	S. America	3500	2900	1800	3700	3100	
		The tallow	....	N. & S. America, Europe & India.	16,025	18,125	15,225	13,800	7100	
		Cheese..........	....	United States, Holland, France, and Italy.	620	515	613	640	597	
		Sugar of milk ...	....	Hamburg	....	12 cwt.	....	....	9 cwt.	Used by the homœopathic druggists.
		Animal charcoal	....	S. America, Holland, and Germany.	210 tons.	301 tons.	119 tons.	76 tons.	220 tons.	Used by the sugar refiners.
	Buffalo (Indian) .... *Bos bubalus* (Linn.).	The hides ...	E. Indies........	E. Indies	hides. 56,154	hides. 24,195	hides. 64,689	hides. 7195	hides. 4349	
		The horns ...			460 tons.	516 tons.	730 tons.	667 tons.	630 tons.	
	Buffalo (American) .... *Bos bison* (Linn.).	The hides (called Robes).	N. America	Canada...........	116 „	30 „	65 „	210 „	118 „	
8th. minantia.	The Alpaca .... *Auchenia llama* (Linn.).	The wool........	Peru and Chili	Valparaiso, Lima, &c.	tons. 820	tons. 873	tons. 960	tons. 941	tons. 1052	
	The Vicuna .... *Auchenia Vicuna* (Linn.).	The wool........	Peru and Chili							

Order Ru.	Goat ...... *Capra Ægagrus* (Gmelin.).	The hair	Persia	Turkey	14,079 lbs	16,873 lbs	14,591 lbs	15,797 lbs	10,277 lbs	
	Camel ...... *Camelus dromedarius* (Cu.).	The hair	Arabia	N. Africa and Turkey.	......	4010	......	10,000		
	Deer (Indian) ...... *Cervus axis* (Cuv.).	The skin	E. Indies	E. Indies	skins. 800	skins. 450	skins. 1200	skins. 570	skins. 763	
		The horns	......	E. Indies	horns. 17,657	horns. 25,890	horns. 27,700	horns. 30,452	horns. 19,868	
	Rein-deer ...... *Cervus tarandus* (Linn. & B).	The tongue	N. of Europe ...	Russia	10 cwt.	......	3 cwt.			
	The Sheep ...... *Ovis aries* (Linn.).	The skin	Persia	Callao and Arica, Valparaiso and Islay, Buenos Ayres, Nassau and Morocco.	skins. 10,631	skins. 8640	skins. 11,080	skins. 10,750	skins. 12,110	
		The wool	......	Europe, Asia, Africa, America, and Australia.	tons. 32,720	tons. 38,860	tons. 41,872	tons. 44,925	tons. 42,604	
Order 7th. Pachydermata.	The Elephant ...... *Elephas africanus* (Cuv.).	The tusks	Africa	Sierra Leone, Loango.	teeth. 2260	teeth. 4843	teeth. 2390	teeth. 2152	teeth. 3040	
	The Indian Elephant ...... *Elephas indicus* (Cuv.).	The tusks	India	E. Indies						
		The hairs	......	E. Indies	......	......	......	......	......	These large hairs are made into bracelets which are occasionally imported as presents.
	Rhinoceros ...... *Rhinoceros indicus* (Cuv.).	The horn or mass of hair from the snout.	E. Indies	E. Indies and Ceylon.	......	......	......	......	......	Occasionally imported, carved into ornaments.
	Hippopotamus ...... *Hippopotamus amphibius* (Linn.).	The teeth	Africa	Western Africa...	6 cwt.	......	12 cwt.	8 cwt.	11 cwt.	Used by the dentists chiefly.
	The Daman ...... *Hyrax capensis* (Cuv.).	A peculiar secretion emitted from the animal, called Hyraceum, the nature of which is not well ascertained.	Cape of Good Hope.	The Cape of Good Hope.	40 tons.	......	......	......	......	This was a mixture of Hyraceum and soil which had been scraped up and sent here to be tried as a substitute for guano.

VERTEBRATA.—Class Mammalia (*continued*).

Nat. Order.	Producing Animal.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Order 7th. Pachydermata.	The Horse .... *Equus caballus* (Linn.).	The hide	....	Buenos Ayres, Monte Video.	hides. 9,200	hides. 9,940	hides. 354,168	hides. 331,553	hides. 180,302	
		Hair of the mane and tail.	....	Ditto	320 tons.	213 tons.	246 tons.	454 tons.	273 tons.	
		The grease	....	Ditto	87 ,,	16 ,,	98 ,,	115 ,,	70 ,,	
	The Hog .... *Sus scrofa* (Linn.).	The skin	....	New York, Monte Video.	....	skins. 400	skins. 763	....	skins. 234	Used by saddlers.
		The flesh salted..	....	United States, Holland, Germany, France.	tons. 7,350	tons. 14,000	tons. 13,160	tons. 9,860	tons. 9,750	
		As bacon ...... As hams	....	Ditto	9,960	12,840	10,690	9,600	8,300	
		The fat or lard...	....	United States ...	11,481	15,692	16,670	11,650	9,318	
		The bladder......	....	United States ...	bladders. 93,000	bladders. 123,000	bladders. 113,300	bladders. 130,000	bladders. 87,000	
		The hair	....	United States ...	5 tons.	....	....	2 tons.		
		The bristles	....	United States ...	15 cwt.	....	41 cwt.			
6th Order. Cetacea.	The Sperm Whale .... *Physeter macrocephalus* (Linn.).	The oil of the blubber.	....	United States ...	885 tuns.	763 tuns.	890 tuns.	970 tuns.	900 tuns.	
		The stearine of the oil, or Spermaceti.	....	United States ...	....	....	6 cwt.			
	The "Right Whale" .... *Balæna mysticetus* (Linn.).	The oil of the blubber.	....	Newfoundland, Iceland, Reijkevig.	tuns. 1,116	tuns. 1,316	tuns. 1,226	tuns. 1,408	tuns. 1,450	
		The baleen or Whalebone.	....	Greenland, United States.	6 tons.	25 tons.	18 tons.	23 tons.	16 tons.	
Order. nivora.	The Silver Fox .... *Canis argentatus* (Cuv.).	The skin	N. America	Canada...........	60 skins.	20 skins.	....	....	30 skins.	
	The Yellow Fox .... *Canis fulvus* (Cuv.).	The skin	N. America	Canada...........	....	....	....	120 skins.		
	The Seal .... *Phoca vitulina* (Linn.), and other species.	The skin	N. of Europe and the Arctic Seas.	Newfoundland...	skins. 162,000	skins. 141,000	skins. 156,000	skins. 148,000	skins. 158,000	
		The oil...........	....	Newfoundland...	780 tuns.	720 tuns.	840 tuns.	856 tuns.	824 tuns.	

5th Car	Bear ... *Ursus Americanus* (Gmelin).	The skin ...	N. America ...	Canada ...	10 skins.	...	26 skins.			
		The fat ...								
	Racoon ... *Procyon lotor* (Cuv.).	The skin ...	N. America ...	Canada ...	60					
	The Sable ... *Mustela Zibellina* (Pallas).	The skin ...	N. America ...	Canada ...	4 dozen.	12 dozen.	7 dozen.	6 dozen.	15 dozen.	
	The Ermine ... *Mustela erminea* (Cuv.).	The skin ...	N. Europe and N. America.	Canada ...	...	...	400 skins.			
	The Morse ... *Trichecus rosmarinus* (Lin.).	The tusks ...	Arctic Seas ...	North Seas ...	...	37 teeth.	...	96 teeth.		
Order 2nd. Quadrumana.	Monkey ... Species unknown.	The skin ...	Western Africa ...	Sierra Leone ...	100 skins.	...	180 skins.	100 skins.	240 skins.	
Order 1st. Bimana.	Man ...	Hair of the female.	... ...	France and Germany.	28 lb.	...	30 lb.			

Thallogens.

	Producing Plant.									
Fungi.	Jew's-ear Fungus ... *Exidia auricula-judæ* (Fries).	The whole pileus	Almost universal	Manilla ...	...	...	...	...	A few pounds only.	Imported for the private use of a Manilla family. Use medicinal.
	Truffle ... *Tuber cibarium* (Sibthorp). Variety, Truffle de Périgord or truffle with the black flesh.	The whole fungus	Europe ...	France ...	...	...	...	...	...	Imported only from France in jars of pickle, probably salt and water. Only the black variety is imported. The quantity cannot be ascertained; but if dry it would not exceed 50 lbs. per annum.

Thallogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Algæ.	Irish Moss .... *Chondrus crispus* (Greville).	The whole thallus	The coasts of Ireland. (Common also on other coasts.) (*Carrigeen.*)	Chiefly from Belfast.	This import being a "*coastwise*" article, it is impossible to ascertain the exact amount, but it is very considerable. No weight is returned to the Customs.					The Irish moss has latterly been largely used for feeding cattle. It is also probably employed in dressing or facing cheap silk goods and for sizing paper. Av. val.: £7 per ton.
	Agar-Agar .... *Fucus spinosus* (Linn.).	The whole thallus	Ceylon and other islands of the Indian Seas.	Ceylon	15 baskets about 10 cwt.	....	....	30 cwt.	....	Used only in dressing cheap silk goods. Small quantities of a sweetmeat made by mixing the jelly of this Fucus with sugar, and cutting it into small cakes, are occasionally imported as presents.
	Agar-Agar or Ceylon Moss... *Plocaria candida* (Nees).	The whole thallus	Ceylon and other islands of the Indian Seas. (Malay. *Sajor carang* and *Agar-agar-carang.* Java. *Bulung.* Macassar *Dougidougi.*).	Ceylon	....	....	....	2 cwt.	....	Only one importation, which still remains on the broker's hands. It is a very different plant to the foregoing.
Lichenes.	Orchella-weed .... *Roccella tinctoria* (De Candolle).	The whole of the thallus.	Found on the sea-side rocks in many parts of the temperate and torrid zones.	Lima, Valparaiso, &c.	tons. 12	tons. 17	tons. 8	tons. 15	tons. 3	Used only for dyeing.
	Angola Orchella-weed ...... *Roccella fuciformis* (De Candolle), and probably other species.	The whole of the thallus.	Sea-side rocks of the Canary Isles, West Coast of Africa, &c.	Loango, Lisbon, & the E. Indies.	30	27	10	28	16	Used only for dyeing.

	Madeira Orchella Weed. *Roccella fuciformis.* var. *β linearis* (Acharius).	The whole of the thallus.	Madeira	Lisbon	1 cwt.					Only one small importation.
	Rock-moss or Tartareous Cudbear. *Lecanora tartarea* (Acharius).	The whole of the thallus.	Various rocky shores in the temperate zones	Lisbon	5 cwt.		8 cwt.			Only twice imported.
	Acrogens.									
Filices.	American Maiden hair. *Adiantum pedatum* (Linn.).	The fronds	N. America	New York	56 lbs.		13 lbs.	27 lbs.	56 lbs.	Imported by the empirics called Coffinites or followers of the so-styled Dr. Coffin.
Filices.	Peruvian Polypody. *Polypodium Calaguala* (Rz.).	The rhizome	Peru (*Ccallahuala.*)	Lima				One small bag containing a single pound.		Used as a medicine; many virtues are attributed to it.
Filices.	Pu-lu. *Cibotium Scheedianum.*	The fine silky hair from the stipes.	Owhyhee and other tropical islands.	Owhyhee						A few pounds only have been imported. It is apparently the same material as the Penghwar Djambi of the Dutch pharmacologists, by whom that is used as a styptic.
	Endogens.									
Graminaceæ.	Wheat. *Triticum vulgare* (Linn.). Varieties *α. æstivum.* *β. hybernum.*	The caryopsis or grain.	Unknown	From nearly all the European ports, and some ports of Asia, N. America and Australia, and sometimes from S. America.	quarters. 70,684	quarters. 66,800	quarters. 176,791	quarters. 28,828	quarters. 612,815	

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
[...]naceæ.	Wheat (*continued*)	The grain pulverized, or flour.	....	Very largely from the United States and British N. America. Occasionally from Chili in S. America and from Australia.	163,359 barrels. sacks. 70,310	83,049 barrels. sacks. 82,085	162,400 barrels. sacks. 50,115	72,126 barrels. sacks. 39,900	274,647 barrels. sacks. 94,200	Barrels and sacks averaging 196 lbs. each.
		The grain granulated, or Semolina.	....	Messina & Trieste	94 cwt.	30 cwt.	76 cwt.	90 cwt.	84 cwt.	Used for making puddings, &c.
				Genoa	18 „	....	....	42 „	10 „	
				Cadiz	80 „	100 „	58 „	67 „	112 „	
				Bordeaux	6 „	15 „	12 „	13 „	8 „	
		The husk of the grain, or Bran.	....	France	436 sacks.	127 sacks.	513 sacks.	312 sacks.	427 sacks.	
				Cadiz	20 „	....	63 „	20 „	48 „	
				Hamburg	550 „	340 „	700 „	450 „	615 „	
		The grain granulated, or Soojee.	....	Calcutta	1 cwt.	....	....	3 cwt.	5 cwt.	Chiefly used as food for infants.
	Barley, *Hordeum distichon* (L.), and its varieties.	The caryopsis or grain.	Unknown	Dantzic and other Baltic Ports.	6011 qrs.	8220 qrs.	8313 qrs.	3620 qrs.	7210 qrs.	
	Oats, *Avena sativa* (L.).	The caryopsis or grain.	Unknown	The Baltic Ports	950 „	513 „	2850 „	392 „	1260 „	
		The meal	....	....	112 brls.	218 brls.	223 brls.	400 brls.	612 brls.	Barrels averaging 196 lbs. each.
	Rye, *Secale cerealia* (L.).	The caryopsis or grain.	The Caucaso-caspian Desert.	Nykjobing	340 qrs.	418 qrs.	730 qrs.	318 qrs.	560 qrs.	
				Constantinople	300 qrs.					
				Havre	19 qrs.					
	Durra or Darri, *Sorghum vulgare* (Persoon).	The ripe caryopsis or grain.	E. Indies (*Joar*, Indian. *Durra*, Arab.)	Turkey	2300 „	1817 „	2700 „	416 „	1100 „	
	Rice, *Oryza sativa* (L.).	....	....	E. Indies	tons. 15,500	tons. 17,400	tons. 13,818	tons. 15,360	tons. 17,083	
		The caryopsis or grain, husked.	E. Indies (*Aruz*, Hindoo. *Paddie*, Malay.)	N. America (U. S.).	460	517	427	1104	1075	

Grami		The grain unhusked, called Paddy.	....	E. Indies and United States.	bushels. 27,384	bushels. 13,343	bushels. 38,467	bushels. 36,351	bushels. 47,895	
	Indian Corn or Maize ...... *Zea Màys* (L.).	The caryopsis or grain, whole.	Tropical America	The U. States, Trieste, &c.	qrs. 278,417	qrs. 435,817	qrs. 217,311	qrs. 620,135	qrs. 309,723	
		The grain ground into meal.	....	The U. States ...	barrels. 30,615	barrels. 31,836	barrels. 28,973	barrels. 11,684	barrels. 2020	Barrels averaging 196 lbs. each.
		The grain husked and broken in the form called Hominy.	....	The U. States ...	47 cwt.	93 cwt.	16 cwt.	27 cwt.	32 cwt.	
	Lemon-grass .... *Andropogon citratum* (De Cand.).	The essential oil of the whole plant.	India and Ceylon	Ceylon	....	8 lbs.	....	....	....	This is the essential oil sold under the name of Citronelle Oil.
	Lemon-grass .... *Andropogon* (sp.?).	The essential oil of the leaves.	Ceylon	Ceylon	....	8 lbs.	....	....	....	This oil is imported and sold under the name of Essence of Verbena; it is confounded with *A. citratum* by Dr. Pereira and others, but is certainly another species. The plant has been raised from seed in the Liverpool Botanic Garden, but has not yet flowered.
	Ginger-grass .... *Andropogon Calamus aromaticus* (Royle).	The essential oil of the leaves.	India .... (*Roosa-ke-til.*)	Calcutta	2 lbs.	....	....	....	....	This is sold under the name of Oil of Rose-scented Geranium; the only importation to Liverpool was the small quantity in 1851 consigned to a local physician for use as a rubefacient in rheumatism.

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
…naceæ.	Khus-khus or Vetiver ...... *Andropogon muricatus* (Retz.).	The dried root...	India .... (*Khus-khus*, and *Vittie-vayr.*)	India	....	....	....	....	....	Small quantities of this sweet-scented root arrive in most vessels from India, but never as regular importations. The Khus-khus received, is generally manufactured into fans, baskets, or mats, often decorated with the elytra of *Buprestis vittata*.
	Job's-tears .... *Coix lacryma* (L.).	The caryopsis or seed.	E. Indies .... (*Ukhburoos*, Bengalee.)	W. Indies........	....	....	....	....	....	Small quantities are occasionally brought from the West Indies (where the plant is now naturalized); they are used frequently as beads for rosaries.
	Timothy Grass................. *Phleum pratense* (L.).	The caryopsis or seed.	Britain........... (*Meadow Catstail Grass.*)	The U. States ...	bushels. 690	bushels. 413	bushels. 711	bushels. 727	bushels. 614	The seed raised in America is much valued for sowing with other grasses in this country.
	Canary Grass .... *Phalaris canariensis* (L.).	The caryopsis or seed.	Britain........... (*Canary Grass.*)	Northern Germany and Holland.	880	657	388	415	673	Used almost wholly for feeding cage-birds.
	Millet .... *Panicum miliaceum* (Lam.).	The caryopsis or seed.	E. Indies .... (*Dukhun*, Bengalee.)	Salonica and Kaffa.	20 qrs.	2 qrs.	....	....	16 qrs.	Used for feeding cage-birds. It is also husked and used for food in puddings, &c.
	Italian Rye-grass.............. *Lolium italicum* (A. Braun).	The caryopsis or seed.	Italy	Leghorn, Venice, and Trieste.	bushels. 2271	bushels. 343	bushels. 618	bushels. 650	bushels. 1137	Used only as an agricultural seed.

Grami	Flote Grass .... *Glyceria fluitans* (R. Br.).	The caryopsis or seed (husked).	Europe........ (*Manna Croup.*)	The Russian Baltic Ports.	....	....	....	....	....	The quantity imported is not ascertainable, as only small quantities are brought in, usually by the masters of vessels as presents. It resembles the Italian Semolina, and is often mistaken for that article.
	Sugar Cane .... *Saccharum officinarum* (Linn.).	Sugar or the crystallizable portion of the juice.	India and China	The E. Indies, W. Indies ..., China ...., Mauritius ..., Manilla ......, Brazil ......, Cuba, &c. ...	tons. 70,030	tons. 61,178	tons. 65,385	tons. 82,701	tons. 71,471	This is the total quantity of raw sugar imported, but much of it is undoubtedly date sugar, and it is impossible to ascertain what proportion.
		Molasses or the uncrystallizable portion of the juice.	....	W. Indies and E. Indies.	9895	5875	12,220	11,877	10,375	
	Reed Canes .... *Arundinaria Schomburgkii* (?).	The culm or hollow stem.	S. America	New Orleans, Savannah and Charleston.	canes. 10,050	canes. 23,615	canes. 46,895	canes. 18,763	canes. 37,987	Chiefly used for fishing rods and for fishing-line winders, which are made of pieces of the thicker portions of the stem.
	Bamboo Canes .... *Bambusa arundinacea* (W.), probably also, *B. gigantea* and other species.	The culm or hollow stem.	E. Indies	E. Indies	....	....	....	....	....	The quantity brought to this country is very large, but the bamboo is never imported as a species of merchandise; the canes are used as dunnage for vessels loaded in India, and are readily bought up for similar purposes upon their arrival in this country.
	Whangee Canes .... *Bambusa nigra?*	The culm........	China	China	" 1300	" 11,000	" 6000	"	" 4000	These are small canes with short internodes; they are used only for walking-sticks. Several other species are also imported, but nothing is known of their origin.

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Cyperaceæ. (R. Br.)	Rush ……… *Scirpus lacustris* (L.).	The stem ………	Europe………	Holland and Belgium.	1143 bundles of 40 lbs. each.	5331 do.	4013 do.	13,000do.	5401 do.	Used by the coopers for placing between the staves of casks, and now rarely by chair-makers and church hassock-makers, &c.
Aroideæ. (Juss.)	Eddoes……… *Caladium esculentum* (Ventenat).	The corm………	S. America ….	W. Indies………	………	………	………	………	………	Vessels frequently bring small quantities of Eddoes for private use only.
Pandanaceæ. (Lindl.)	Screw-pine ……… *Pandanus odoratissimus* (L. fil.).	The leaves ……	E. Indies ………	Mauritius and Manilla.	………	………	………	………	………	Although no portion of this plant is recognized as an article of importation, yet immense quantities reach this country in the form of sugar-bags which are made by plaiting the long sword-shaped leaves.
…ceæ.	The Rattan Palm ……… *Calamus rotang* (L.), *C. rudentum* (Lour.), *C. Royleanus* (Griff.), and other species.	The long thin climbing stems.	India and the Indian Archipelago.	India ………	53,245 bundles of 100 canes	40,700 do.	51,750 do.	64,347 do.	63,219 do.	The chief use for these canes in Europe, is for chair-bottoms; but they are of very great utility to the inhabitants of India and China. Av. val.: 1*s.* 6*d.* to 3*s.* per 100.
	The Malacca Cane ……… *Calamus scipionum* (Lour.).	The long internodes of the stem.	Sumatra ……… (*Heotan*, Cochin China.)	China and Singapore.	canes. 630	canes. 2004	canes. 813	canes. 1155	canes. 753	Used only as walking-sticks; the natives colour them by hanging them in the smoke of wood-fires.

Palmæ	The Penang-Lawyer Cane ... *Licuala acutifida* (Mart.).	The young stems	Penang............ (*Plass - tikooss*, Malay.)	China	400	215	521	317	500	These small palm-stems are much valued as walking - sticks when dressed and polished.
	Little Coker-nut .... *Jubæa spectabilis* (H.B.K.).	The nuts	Chili............... (*Coquito.*)	New Granada ...	6 bush.	....	....	....	30 bush.	These nuts are eaten by children.
	Vegetable Ivory or Corrosso-Nuts. *Phytelephas macrocarpa* (Ruiz. & Pav.).	The nuts	New Granada ...	Santa Martha ...	2 tons.	5 tons.	....	16 cwt.	$2\frac{1}{2}$ tons.	Used by the turners as a substitute for ivory.
	The Sago Palms .... *Saguerus saccharifer* (Blume), *Sagus lævis* (Rumph.), *Sagus genuina* (Rumph.), and probably several other species.	....	....	....	....	....	....	....	....	Sago flour is imported for use as starch in the manufactories; Pearl Sago only as food.
		Sago Flour ...... The starch obtained by washing the medulla or pith of the stems.	The Indian Archipelago. (*Sagu*, Malay.)	Singapore	3605tons.	3657tons.	4012tons.	4220tons.	4556tons.	The number of packages received in 1851 was 41,800 of all kinds of Sago.
		Pearl Sago ...... The starch granulated or pearled.	....	Singapore	585 ,,	336 ,,	375 ,,	590 ,,	654 ,,	
	The Tecum Palm .... *Astrocaryum vulgare* (Mart.).	Fibres of the young leaves.	Brazil .... (*Tucum.*)	Para...............	....	....	....	....	20 lbs.	Only one small lot has been imported, for experiment; the fibre is very fine, of a green colour and somewhat like sheep's wool.
	Palmetto Palm .... *Borassus flabelliformis* (L.).	The leaves	India and Africa (*Tal, Tala, Talgaha, Trinrajan, Loutar, Palmeira.*)	India	bundles. 850	....	....	....	bundles. 2000	Very large quantities of Palm leaves manufactured into mats find their way into this country, and are made into bags for containing merchandise, but it is quite impossible to determine the species from which they are obtained. The pal-

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Palmaceæ (*continued*).	Palmetto Palm (*continued*)...	Plait made of the leaves.	....	....	....	....	....	....	4000 hats made of the plait from Singapore.	metto thatch is now only imported as dunnage for ships; and the plait made up into hats.
	The Sugar Date .... *Phœnix sylvestris* (Rox.).	....	India	Bombay and Calcutta.	....	....	....	....	....	The sugar made from these and other palms is very largely imported; but it is so mixed up with the cane sugar, that it is impossible to ascertain the quantities.
		Sugar made from the juice.								
	The Gomuti Palm .... *Arenga saccharifera.*	....	India							
	The Coquilla Palm .... *Attalea funifera* (Martius).	The nut	Brazil	Chiefly from Para and Bahia.	nuts. 2000	....	....	nuts. 12,000	....	Coquilla nuts are only occasionally imported; they are used by turners for making small handles for cabinet drawers, parasols, &c.
		The fibrous rete produced by the breaking up of the petioles.	Brazil	Chiefly from Para & Bahia.	196 tons.	516 tons.	530 tons.	518 tons.	630 tons.	It is only lately that the Piassava of commerce has been attributed to both these palms, and the question is not yet fairly decided.
	The Piacaba Palm .... *Leopoldina piacaba* (Wallace).	The fibrous rete.	Brazil	Maranham and Para.						
	The Oil Palm .... *Elais guineensis* (Jacq.).	The oil obtained from the nut.	The Guinea Coast	The Guinea Coast	tons. 23,800	tons. 19,950	tons. 22,540	tons. 26,980	tons. 30,500	This enormous quantity of Palm Oil is used chiefly in the manufacture of soap and candles.

	The Cocoa Palm .... *Cocos nucifera* (L.).	The nut	E. Indies	From the W. Indies and S. America.	nuts. 146,131	nuts. 273,000	nuts. 265,120	nuts. 257,000	nuts. 258,000	To understand the extent to which this trade excites native industry, it must be borne in mind that six pounds of the oil is a large yield for one palm.
		The oil from the nut.	....	Ceylon	149 tons.	317 tons.	516 tons.	815 tons.	821 tons.	
		The fibrous mesocarp or coir.	.... (*Kyar.*)	Bombay	926 „	1020 „	1100 „	2006 „	2257 „	
	The Date Palm .... *Phœnix dactylifera* (L.).	The fruit	E. Indies	Gibraltar and Alexandria.	36 cwt. 17 „	23 cwt.	50 cwt.	18 cwt.	56 cwt.	
Zosteraceæ.	Sea-wrack or Alva marina ... *Zostera marina* (Linn.).	The leaves	The bottom of seas in northern and temperate latitudes.	Holland	6 cwt.	....	....	....	....	Only imported as a packing material, which is sometimes collected for stuffing the beds and cushions of the poor.
Bromeliaceæ.	Pine-apple .... *Ananassa sativa* (R. Brown).	The fruit	S. America .... (*Nanas*).	W. Indies........	28,000	20,100	18,000	27,000	12,000	
		Fibres of the leaves.	....	Manilla	....	....	32 cwt.	....	....	A very fine long fibre, of which eight bales were imported. Sir William Hooker doubts whether it is the produce of the *A. sativa*; but as the species are all natives of the S. American continent, and only one is used for its fruit, it is improbable any other would be cultivated in the E. Indies.
	Spanish Moss .... *Tillaudsia usneoides* (Lin.).	The subcortical portion of the aerial roots.	W. Indies........	Brazil	....	....	....	....	1 cwt.	Used as a substitute for horsehair in stuffing. This small importation was for experiment only.

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Amaryllidaceæ.	American Aloe .... *Agave Americana* (Linn.).	Fibres of leaves..	S. America. (*Manguey and Metl.*)	Vera Cruz, &c....	2 tons.	....	....	30 tons.	170 tons.	Now used very largely as a substitute for bristles in brushes, for horse-hair in making crinoline, and, when twisted, for stuffing cushions. (1858.)
Iridaceæ.	Saffron.......................... *Crocus sativus* (Allioni).	The dried stigmata.	Asia Minor	Spain	27 lbs.	22 lbs.	....	7 lbs.	115 lbs.	
	Iris or Orrice Root .... *Iris florentina* (Linn.).	The rhizomes decorticated.	S. Europe.........	Leghorn	....	....	....	3 cwt.	....	Used only in perfumery.
Musaceæ.	Plantain .... *Musa textilis* (Don Luis Nee).	Fibres of the petioles called Manilla hemp.	Indian Islands, the Philippines. (*Abaca.*)	Manilla	655 tons.	415 tons.	873 tons.	345 tons.	2325tons.	Used for cordage.
	Banana .... *Musa sapientum* (Linn.).	The fruit	The tropics generally.	W. Indies.........	....	....	....	....	....	A few clusters are constantly to be found in the Liverpool fruit shops in the season, usually brought by captains on their own account, not as cargo.
Zingiberaceæ.	Ginger .... *Zingiber officinale* (Roscoe).	The rhizomes ...	Asia (?)	E. and W. Indies, Africa.	81 tons.	139 tons.	89 tons.	45 tons.	17 tons.	
		The rhizome preserved in sugar.	....	China & E. Indies, W. Indies.	....	....	....	....	....	A large quantity is received, preserved as a sweetmeat; but the exact weight cannot be obtained.
	Turmeric .... *Curcuma longa* (Linn.), and other species.	The rhizomes ...	Asia	E. Indies	389 tons.	215 tons.	287 tons.	....	....	Used for dyeing.
	Guinea Grains, or Grains of Paradise. *Amomum granum Paradisi* (Afzelius), and *A. melegueta* (Roscoe).	The seeds.........	Sierra Leone, &c.	Sierra Leone ...	....	16 cwt.	21 cwt.	....	....	Uses pharmaceutical.

	Malabar Cardamom .... *Elettaria cardamomum* (Maton).	The dried fruit or capsule with seeds.	Malabar	Calcutta	10 cwt.	3 cwt.	7 cwt.	....	....	Pharmaceutical.
	Ceylon Cardamom .... *Elettaria major* (Smith).	The dried fruit or capsule with seeds.	Ceylon	Ceylon	....	....	14 cwt.	....	....	Pharmaceutical.
Marantaceæ.	Arrowroot .... *Maranta arundinacea* (Linn.).	Fecula of the rhizomes.	W. Indies........	W. and E. Indies and Africa.	6 tons.	5 tons.	16 tons.	8 tons.	27 tons.	Used only for food.
Marantaceæ.	Tous les Mois .... *Canna edulis?* (Ker.).	Fecula of the rhizomes.	W. Indies........	St. Kitts	2 cwt.	....	....	3½ cwt.	....	Used only for food.
Orchidaceæ.	Vanilla .... *Vanilla aromatica* (Swartz) and *V. planifolia* (?).	The seed-pods...	Mexico...........	Vera Cruz	....	8 lbs.	....	....	....	Used in perfumery and for flavouring confectionery, &c.
Orchidaceæ.	Salep .... Various species of *Eulophia* and *Orchis*.	The tubers dried	India .... (*Salep Misree.*)	E. Indies........	12 lbs.	57 lbs.	....	....	18 lbs.	Exact use not known, but it is supposed that the chocolate-makers use all which is imported for grinding up with the cocoa.
Orontiaceæ.	Sweet-flag .... *Acorus calamus* (Linn.).	The rhizomes ...	The banks of European rivers.	Hamburg	....	2 cwt.	....	....	....	Pharmaceutical.
Liliaceæ.	The Aloe .... *Aloe vulgaris* (Lam.).	The inspissated juice.	E. and W. Indies and S. Europe.	Barbadoes	7 cwt.	....	13 cwt.	11 cwt.	8 cwt.	Pharmaceutical.
Liliaceæ.	The Squill .... *Scilla maritima* (Linn.).	The bulb (sliced and dried).	Shores of the Mediterranean.	Malta	....	....	5 cwt.	....	....	Pharmaceutical.
Liliaceæ.	Garlic .... *Allium sativum* (Linn.).	The bulb	Doubtful, probably India.	The Mediterranean Ports.	....	....	....	....	....	Small quantities are frequently brought by the Spanish and Italian sailors and sold in the town.

Endogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Liliaceæ.	The Onion .... *Allium cepa* (Linn.).	The bulb	Egypt?	Spain & Portugal	bushels. 1328	bushels. 1101	bushels. 1330	bushels. 1218	bushels. 1423	
Liliaceæ.	The Grass Tree .... *Xanthorrhœa arborea* (Rt. Brown).	The yellow resin called Gum acaroides.	Australia	Australia	....	....	5 tons.	....	....	Used as a substitute for gum benzoin in veterinary medicine; but it is not much employed.
Dioscoreaceæ.	Yams .... *Dioscorea alata* (Linn.).	The tubers	E. Indies	W. Indies	....	....	....	....	....	Never imported for commercial purposes; but small quantities are continually arriving as presents.
Smilaceæ.	Sarsaparilla .... *Smilax medica* (Schlectendahl). *S. officinalis* (H. B. K.). *S. papyracea* (Poiret), and probably other species.	The roots	S. America	Vera Cruz ... La Guayra ... Maranham ...	115 cwt.	127 cwt.	114 cwt.	119 cwt.	137 cwt.	

Exogens.

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
	Dantzic Deal, Spruce Fir, or Spruce. *Abies excelsa* (Poiret).	The timber	N. Europe	The Baltic Ports	cubic ft. 674,139	cubic ft. 630,200	cubic ft. 653,240	cubic ft. 666,611	cubic ft. 448,243	
	Dantzic Fir, Riga Fir, and Prussian Deal. *Pinus sylvestris* (Linn.).	The timber	N. Europe	The Baltic Ports	1,732,500	1,122,750	1,243,700	1,812,750	1,824,800	

Coniferæ.	White Pine or Deal .... *Pinus strobus* (Linn.).	The timber	N. America	N. America (Canada).	4,727,764	6,772,890	6,347,436	6,952,676	5,229,948	
	Yellow Pine or Deal .... *Pinus palustris* (H. K.).	The timber	N. America	N. America (Canada).						
	Pitch Pine .... *Pinus rigida* (Mil.).	The timber	Virginia and Georgia.	United States ...	299,857	467,963	677,854	733,136	553,914	
	Red Cedar .... *Juniperus virginiana*(Linn.)	The timber	United States ...	United States ...	15,332	10,671	16,077	9,743	12,416	
	White Spruce .... *Abies alba* (H. K.).	The timber	N. America	N. America (Canada).	343,597	536,784	461,911	765,381	1,071,693	
	Hemlock Spruce............... *Abies canadensis* (H. K.).	The timber	N. America	Canada............	22,973	27,461	25,666	21,874	29,861	
	Turpentine .... *Pinus palustris* (H. K.); *Pinus Tæda* (Linn.); and probably other species.	The oleo-resin which flows from incisions of the stem.	N. America	United States ...	tons. 5450	tons. 4950	tons. 3095	tons. 2700	tons. 2080	
		Essential oil of the oleo-resin or spirit of turpentine.	N. America	United States ...	gallons. 360	gallons. 866	gallons. 576	gallons. 416	gallons. 970	
		The resin of the oleo-resin, or rosin.	N. America	United States ...	tons. 190	tons. 217	tons. 256	tons. 237	tons. 296	
	Tar .... *Pinus sylvestris* (Linn.); *Pinus palustris* (H. K.); and other species.	The oleo-resin procured by destructive distillation.	N. of Europe and N. America.	The Baltic Ports & United States.	300	3530	3330	3400	4500	
		The solid residuum or pitch.	....	....	70	160	112	40	81	
	Canada Balsam .... *Abies balsaminea*(Michaux)	The oleo-resin of the stem.	N. America	Canada............	....	....	....	8 cwt.	....	Used chiefly by opticians and microscopists.
	Dammar .... *Dammara orientalis* (Lamb.).	The resin.........	Indian Islands...	E. Indies	15 cwt.	....	4 tons.	....	....	Used in varnishes.

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Coniferæ.	Kawrie or Cowdie Pine ...... *Dammara australis* (Lambert).	The resin.........	New Zealand ...	New Zealand ...	60 tons.	150 tons.	....	90 tons.	....	Used in varnishes.
	Juniper .... *Juniperus communis* (Linn.).	The berries	N. Europe	Hamburg.........	15 cwt.	....	....	25 cwt.		
Myri-caceæ.	Bog Myrtle .... *Myrica cerifera* (Linn.).	Wax procured from the seeds, or Myrtle wax.	N. America	New Jersey	....	3 cwt.	....	....	....	Imported for experimental purposes in pharmacy.
Urti-caceæ.	China Grass..................... *Bœhmeria nivea* (Kæmp.).	The fibres of the stem.	China and India. (*Rheea* or *Ramee*) Indian.	E. Indies	10 tons.	40 tons.	....	....	....	For weaving.
Cannabi-naceæ.	Hemp .... *Cannabis sativa* (Linn.).	The fibres of the stem.	India	Europe......... N. America ... E. Indies	5112tons.	4340tons.	6460tons.	6300tons.	4220tons.	
	Hop .... *Humulus Lupulus* (Linn.).	The dried strobiles.	Europe............	N. America and Germany.	3 „	....	11 „	$2\frac{1}{2}$ „	5 „	
Moraceæ.	The Fig .... *Ficus carica* (Linn.).	The fruit	Asia	Turkey, Greece...	304 „	320 „	297 „	317 „	389 „	
	Fustic .... *Maclura tinctoria* (D. Don.).	The timber	S. America	Savanilla and W. Indies.	9950 „	3050 „	3700 „	6150 „	7950 „	Used in dyeing.
[...]biaceæ.	India-rubber .... *Siphonia elastica* (Persoon).	The hardened juice.	Brazil .... (*Siringa*).	Brazil	213 „	300 „	337 „	250 „	287 „	
	Cascarilla...................... *Croton eleutheria* (Swartz).	The bark	The Bahamas and Jamaica.	The Bahama Islands.	27 „	4 „	....	16 „	20 „	
	Croton .... *Croton tiglium* (Lam.).	The oil of the seeds.	India and Ceylon	E. Indies	5 cwt.	....	....	4 cwt.	....	Seeds only imported.

Euphor	The Castor Plant .... *Ricinus communis* (Linn.).	Castor oil from the seeds.	India	E. and W. Indies.	78 tons.	27 tons.	47 tons.	35 tons.	79 tons.	
	Physic Nut .... *Curcas purgans* (Adan.).	The seed	The Cape de Verde Islands.	The Cape de Verdes and Lisbon.	....	50 qrs.	....	....	....	Used only for expressing oil.
		Oil expressed from the seeds.	....	Lisbon	1400tuns.	1800tuns.	1576tuns.	2000tuns.	2012tuns.	Employed chiefly in dressing woollen cloths.
	Tapioca .... *Manihot utilissima* (Pohl.).	The fecula of the root, in the form of Tapioca	Brazil	Brazil	720 tons.	650 tons.	713 tons.	735 tons.	711 tons.	
		In the form of Farinha or Mandioca meal......	....	Brazil	300 ,,	415 ,,	410 ,,	215 ,,	327 ,,	
	Box .... *Buxus sempervirens* (Lin.).	The wood	Europe............	Smyrna and Constantinople.	925 ,,	1015 ,,	876 ,,	963 ,,	990 ,,	Used chiefly in making rollers for printing calicoes, &c., and for engraving upon.
Corylaceæ.	The Oak .... *Quercus pedunculata* (W.); and *Q. sessiliflora* (Sm.).	The timber	Europe............	Baltic Ports......	cubic ft. 240	cubic ft. 386	cubic ft. 349	cubic ft. 345	cubic ft. 426	
		The bark	....	Holland and Belgium.........	3177tons.	3008tons.	4965tons.	2980tons.	4600tons.	
	Quebec Oak..................... *Quercus alba* (L.).	The timber	N. America	Canada............	cubic ft. 295,000	cubic ft. 257,000	cubic ft. 260,000	cubic ft. 279,000	cubic ft. 332,000	
	Valonia .... *Quercus Ægilops* (L.).	The acorn cup...	The Levant	Smyrna and the Greek Islands.	5178tons.	5162tons.	6180tons.	7768tons.	4476tons.	Used only for tanning.
	Dyers' Oak or Quercitron Oak. *Quercus tinctoria* (L.).	The bark crushed	United States ...	United States ...	1520 ,,	1676 ,,	1613 ,,	1850 ,,	1824 ,,	Used in dyeing and tanning.
	Cork Oak........................ *Quercus suber* (L.).	The bark	S. Europe	Spain, Portugal, and France.	260 ,,	230 ,,	215 ,,	256 ,,	363 ,,	
	Gall Oak .... *Quercus infectoria* (Oliv.).	The galls formed by species of *Cynips*.	Turkey............	Smyrna and Constantinople.	270 ,,	286 ,,	311 ,,	298 ,,	370 ,,	
	The Hazel .... *Corylus avellana* (Linn.).	The nut	Europe and Asia.	Spain, Smyrna, France, Italy, &c.	bushels. 46,300	bushels. 44,300	bushels. 49,800	bushels. 52,000	bushels. 47,600	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Corylaceæ.	Chestnut ... *Fagus castanea* (L.).	The nut ...	...	Spain, France ...	530 bush.	610 bush.	650 bush.	590 bush.	620 bush.	
	Beech (Circassian) ... *Fagus* (sp. ?).	The timber ...	...	The Black Sea...	...	30 logs.	...	...	...	A fine furniture wood, imported for the first time.
Juglandaceæ.	Walnut ... *Juglans regia* (Linn.).	The nut ...	Persia ...	Germany, France, and Italy.	bushels. 2300	bushels. 2100	bushels. 3000	bushels. 2560	bushels. 2350	
		The timber ...	...	Italy, Germany, the Black Sea, N. America.	...	...	cubic ft. 58,000	cubic ft. 120,000	...	That from the Black Sea is Circassian. The total quantity from Circassia was 278,000 superficial feet of 1 inch thickness; this mode of calculating is common in the timber trade.
	Black Walnut ... *Juglans nigra* (Linn.).	The nut ...	N. America ...	Canada...	...	...	...	...	5 bush.	
	Hog Walnut ... *Juglans porcina* (Mich.).	The nut ...	N. America ...	Canada...	3 bush.	...	...	2 bush.		
	Hickory ... *Carya alba* (Nuttall), and other species.	The nut ...	N. America ...	United States ...	12 bush.	70 bush.	110 bush.	65 bush.	96 bush.	
		The timber ...	...	United States ...	...	...	250 cu. ft.			
	The Pecan-nut Tree ... *Carya olivæformis* (Nutt.).	The nut ...	N. America ...	United States ...	61 bush.	58 bush.	112 bush.	73 bush.	105 bush.	
Atherospermaceæ.	Plume Nutmeg ... *Atherosperma moschata* (Lab.).	The bark ...	N. Holland ...	Australia ...	...	...	...	...	...	Only a few pounds imported in 1853, for medicinal purposes.
...ceæ.	The Nutmeg ... *Myristica moschata* (Thumberg), and other species.	The kernel of the fruit.	Molucca Islands.	St. Vincent, W. I., Penang, Singapore.	lbs. 14,059	lbs. 7,680	lbs. 9,456	lbs. 11,071	lbs. 15,180	

Myristic[æ]		The mace or arillode of the nut.	......	Singapore	1,008 „	448 „	984 „	18,700 „	961 „	
		The fruit or pericarp.	......	E. Indies	......	......	......	......	......	Occasionally imported as a sweetmeat preserved in sugar.
		The expressed oil of the kernel.	......	......	......	30 lbs.	......	......	......	This is a vegetable fat called Oil of Mace.
		The essential oil of the kernel.	......	......	......	7 lbs.				
Menispermaceæ.	Cocculus Indicus ...... *Anamirta cocculus* (W. & A.).	The berries	Malabar	E. Indies	......	......	10 cwt.			
Cucurbitaceæ.	Colocynth ...... *Citrullus colocynthis* (Sc.).	The dried gourd.	Turkey, &c.	Spain and the Levant.	8 cases, about 5 cwt.	......	......	......	5 boxes, about 2 cwt.	
	Water Melon ...... *Cucurbita citrullus*, var. *Jace* (Ser.).	The gourd	S. Europe	Spain and Portugal.	300	150	280	400	450	
Flacourtraceæ.	Arnotto or Anotto ...... *Bixa orellana* (L.).	The pulp from the seeds.	S. America	Brazil	11 tons.	18 tons.	13 tons.	20 tons.	25 tons.	
Cruciferæ.	Mustard Seed (East Indian). *Sinapis toria.* *S. nigra* (Linn.). *S. glauca.* And probably other species, usually mixed together.	The ripe seed ...	Asia and Europe. (*Sursee seed*, & various other local names.)	Bombay	583 qrs.	477 qrs.	673 qrs.	766 qrs.	270 qrs.	Used only for expressing oil.
	Rape Seed (East Indian) ... Probably a species of *Sinapis.*	The ripe seed ...	Asia	Bombay	911 „	326 „	890 „	1,256 „	3,028 „	Ditto. Av. value 40*s.* per qr.
	Rape Seed (European) ...... *Brassica Napus* (Linn.). Var. *oleiferus* (DeCand.).	The ripe seed ...	Europe......	Hamburg and Holland.	150 „	......	16 „	......	......	Ditto.

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Resedaceæ.	Weld or Dyer's Weed......... *Reseda luteola* (Linn.).	The whole plant	Europe...........	Havre	....	....	....	3 tons.	7 tons.	
Capparidaceæ.	The Common Caper .... *Capparis spinosa* (Linn.).	The flower-buds pickled.	South of Europe	France, Spain, & Italy.	216 galls.	420 galls.	317 galls.	550 galls.	435 galls.	
Sterculiaceæ.	South American Silk Cotton or Vegetable Silk. *Chorisia speciosa* (St. Hil.).	The silky hairs which envelope the seeds.	Brazil. (*Arvore de Piana.*)	Brazil	....	....	....	....	....	One small quantity was imported in 1851, and forwarded to Manchester for experiment.
	West Indian Silk Cotton ... *Eriodendron anfractuosum* (V); *E. occidentale* (DeCand.).	The silky hairs which envelope the seeds.	W. Indies.........	The Caribbee Islands, W. Indies, and British Guiana.	....	....	....	....	....	Small quantities frequently come, but not as regular trade importations. It is used for stuffing cushions, &c.
	East Indian Silk Cotton or Moc-main. *Bombax pentandrum* (L.).	The silky hairs which envelope the seeds.	E. Indies	E. Indies	....	....	....	....	....	Small quantities occasionally arrive chiefly as packing; it is used in stuffing the pads of trusses.
Byttneriaceæ.	The Cocoa or Cacao .... *Theobroma Cacao* (Linn.).	The seeds which are contained in a large fleshy capsule.	S. America ...... (*Cacao.*)	W. Indies, S. America, and occasionally in very small quantities from the E. Indies, where it is now cultivated.	549 tons.	547 tons.	700 tons.	596 tons.	199 tons.	Av. val.: 35*s.* per cwt.
		The husk of the seeds.	....	Trieste, Bilbao, Bordeaux.	19 „	22 „	19 „	15 „	17 „	Imported from the Levant, &c., and sent to Ireland, where it is used under the name of *Miserable.*

Malvaceæ.	Cotton			The United States	lbs. 454,796,100	lbs. 576,998,016	lbs. 378,434,008	lbs. 549,593,856	lbs. 539,742,080	Av. val.: highest quality, 2*s.* 6*d.*; lowest quality, 4*d.*
	Gossypium herbaceum (L.) ,, *peruvianum* (Cuv.) ,, *barbadense* (L.).		E. Indies S. America W. Indies	Pernambuco Aracati Bahia Maceio Maranham	36,939,320	48,083,200	43,952,208	35,048,422	45,214,848	Av. val.: 6*d.*
		The hairs which densely cover the testa of the seeds.		Surinam Demerara	322,800	644,448	192,192	192,192	279,328	Av. val.: 6*d.*
				West Indian Bahama Carthagena Laguira	2,114,400	2,486,736	1,018,752	2,258,592	2,327,472	Av. val.: 6*d.*
				Smyrna Egypt	25,012,400	73,177,200	41,700,000	29,176,800	44,333,600	Av. val.: 8*d.*
				Surat Madras Bengal	92,840,000	42,201,900	97,393,500	71,122,800	83,799,600	Av. val.: 3*d.*
		The seed		New Orleans, &c.	bushels. 5	...	...	bushels. 150	bushels. 400	Partly for transmission to other countries as seed, and partly for expressing oil.
		Oil from the seed			...	gallons. 560	gallons. 550	gallons. 1,100	gallons. 270	The oil is used for dressing woollen fabrics.
		Oil cake			...	15 tons.	2 tons.	...	7 tons.	For feeding cattle.
	The Ochra Plant *Abelmoschus moschatus* (L.).	The seed-pod	E. and W. Indies (*Okro, Gombo, Bandkai, &c.*)	Greece	...	...	...	...	...	The pods of this plant are used both fresh and dried as an esculent vegetable. They are not imported as articles of commerce; but small quantities frequently arrive for private consumption amongst the Greek merchants of this town.
	The Sun Hemp *Hibiscus cannalinus* (L.).	The fibre of the stem.	E. Indies (*Sun or Sunn.*)	E. Indies	cwt. 23	cwt. 276	cwt. 1,807	cwt. 11,605	cwt. 6,457	Used chiefly by the rope-makers.

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Tiliaceæ.	The Lime or Linden Tree ... *Tilia europæa* (L.).	The bast or alburnum.	Northern Europe	Russia	....	....	....	....	....	Linden bast is only imported in the form of mats from the Baltic Ports, chiefly from Archangel. The number of mats imported, either new or as dunnage for grain vessels is enormous, and they form an important branch of commerce, but we have no means of ascertaining the exact quantity introduced.
	Jute................................ *Corchorus capsularis* (L.).	The fibre of the stem.	India	The E. Indies ...	tons. 12,967	tons. 9,303	tons. 8,918	tons. 1,425	tons. 12,589	
	Elæocarpus ganitrus Gærtner).	The curiously furrowed fruit.	India	The E. Indies ...	....	....	....	....	....	These hard bony fruits are never imported as articles of commerce; but they are brought in considerable numbers made up into necklaces and rosaries of great beauty.
Polygalaceæ.	Snake root .... *Polygala Senega* (Linn.).	The dried root...	United States (South).	United States ...	....	5 cwt.	8 cwt.	....	7 cwt.	Used only in medicine.
	Rhatany root .... *Krameria triandra* (Ruiz and Pavon).	The dried root...	S. America (Peru)	Peru..............	....	....	....	....	12 cwt.	Used in medicine, and to colour port wine.
	Litchi tree .... *Nephelium Litchi* (Cambess).	The fruit	China	Canton............	2 chests.	....	80 chests.	10 chests.	....	Each chest contains an earthen jar which holds about one peck. This fruit is often offered for sale in the shops of Liverpool at about 6*d*. per doz.

Sapindaceæ.	Longan tree. *Nephelium Longanum* (Cambess).	The fruit	China (*Longan.*)	Canton					1 chest.	This fruit is very rarely seen, and is not so highly esteemed as the previous one, probably on account of its less beautiful appearance.
	Soap-berry tree. *Sapindus saponaria* (L.).	The fruit	S. America and W. Indies.	Carthagena, Demarara, and W. Indies.					1 bag.	The single importation here mentioned was sent from Carthagena to be tried for cleansing cloth. The seeds without the pulp are often imported for rosary beads and as curiosities.
Aceraceæ.	The Maple. *Acer saccharinum* (L.).	The timber	N. America	United States and Canada.	1653 planks; 30 cases, veneers.	559 planks; 50 cases, veneers.	559 planks; 20 cases, veneers.	549 planks; 60 cases, veneers.	119 planks; 80 cases, veneers.	Two varieties of maple wood are imported—the plain, and that called Bird's-eye; both are used chiefly in cabinet work and for picture frames.
		The saccharine juice.		Canada						Maple sugar is not imported for commercial purposes, but is very frequently brought in small quantities as presents, often in pretty little baskets of bark work, which are sometimes ornamented with the small quills of Hystrix dorsata, dyed with brilliant colours.
Dipteraceæ. (Lindl.)	Anime tree. *Vateria indica* (Roxb.).	The gum-resin	India	Bombay			5 tons.		$3\frac{1}{2}$ tons.	Used for varnishes.
	Dhoona tree. *Shorea robusta* (Roxb.).	The gum-resin	India	Bombay		16 cwt.				Only one experimental importation.
	Vegetable Tallow tree (?).	Veget. fat, probably procured from the seeds.		Singapore	3 tons.	6 tons.	$4\frac{1}{2}$ tons. 8 tons.		15 tons.	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Dipte-raceæ.	Wood oil tree .... *Dipterocarpus turbinatus.*	Oil from the stem.	Bengal	E. Indies	....	....	....	....	2 gallons.	Only one experimental importation.
Ternstrœ-miaceæ.	Tea .... *Thea viridis* (L.), and *Thea Bohea* (?) (L.).	The dried leaves.	China	China, E. Indies (Assam).	lbs. 16,781,049	lbs. 13,224,994	lbs. 15,509,157	lbs. 13,142,959	lbs. 11,047,226	
		The seed	....	....	....	80 chests, ab. 2 tons.	....	....	....	Probably for expressing oil.
		Oil of the seed...	....	....	36 gall.					
Rhizo-bolaceæ.	The Souari Nut .... *Caryocar butyrosum* (W.). *Pekea tuberculosa* (Aubl.).	The nuts	Guiana........	Demerara	....	....	....	....	....	No regular importations take place; but small lots find their way into the Liverpool fruit-shops, purchased most likely from the masters of ships.
Anonaceæ.	Lancewood .... *Duguetia quitarensis* (Schomb.).	The timber	W. Indies........	W. Indies........	pieces. 8,285	pieces. 5,394	pieces. 6,486	pieces. 10,514	pieces. 4,175	The pieces are poles about 20 feet in length and 8 or 10 inches in diameter, with the bark upon them. They appear to be the entire stems of the tree, and are generally used for making the shafts for gigs and other carriages.
	Black Hellebore .... *Helleborus niger* (L.).	The root and rhizome.	Europe........	Hamburg........	8 cwt.	....	....	6 cwt.		
ceæ.	Gold Thread .... *Coptis trifolia* (Salisbury).	The root	N. America	United States ...	....	....	....	....	....	Small quantities come from time to time compressed into small squares. It is imported for the use of the empirics called Coffinites.

Ranuncul[illegible]	[illegible] seed .... *Nigella sativa* (L.).	The seed	E. Indies	E. Indies	....	....	....	....	....	Never imported as an article of commerce, but frequently brought with other small matters as presents. It is chiefly used to prevent the ravages of moths.
	Stavesacre .... *Delphinium Staphisagria* (Linn.).	The seed	S. Europe........	The Levant	2 sacks, about 3 cwt.	6 cwt.	....	4 cwt.	....	Pharmaceutical.
Papaveraceæ.	Opium .... *Papaver somniferum* (Linn.)	The hardened juice of the unripe capsules.	Asia and Egypt..	The E. Indies and Constantinople.	25 cwt.	471 cwt.	430 cwt.	284 cwt.	350 cwt.	
		The seed	....	Bombay	....	....	....	150 qrs.	300 qrs.	Used for expressing oil.
	Blood-root .... *Sanguinaria canadensis* (Linn.).	The dried roots..	N. America	New York	....	....	....	....	....	Small parcels of this drug, prepared in the United States by the community called Shakers, are frequently imported for the empirics called Coffinites.
Vitaceæ.	The Vine........ *Vitis vinifera* (L.).	The ripe grapes	Uncertain	Lisbon, Hamburg.	brls. & boxes. 6786 cwt.	brls. & boxes. 7506 cwt.	brls. & boxes. 3284 cwt.	brls. & boxes. 3356 cwt.	brls. & boxes. 2897 cwt.	The contents of these packages average about 56 lbs.
		The dried grapes or raisins.	....	Malaga, Valencia, Denia, Smyrna.	80,437	79,306	82,711	79,339	61,456	
		The dried seedless grapes, currants, and	....	Greece and the Jonian Islands.	53,789	58,791	49,640	43,557	41,108	
		Sultanas	....	Smyrna	6036	7118	5311	5168	8271	
Guttiferæ.	Canella........ *Canella alba* (Murray).	The bark	W. Indies and S. America.	The Bahama Islands.	37	....	....	15	28	Materia Medica.
Ericaceæ.	Partridge-berry .... *Gaultheria procumbens* (Linn.).	The essential oil of the leaves—called Oil of Winter-green.	N. America	New Jersey and the United States.	....	....	....	....	24 lbs.	Used in perfumery; but rarely imported into Liverpool.

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Aurantiaceæ.	The Lemon .... *Citrus Limonum* (Risso).	The fruit	Asia	Sicily, Italy, Portugal, France (Marseilles).	packages. 4408	packages. 5009	packages. 5110	packages. 6212	packages. 6127	Averaging 2 bushels to each package.
		The essential oil of the rind.	....	Sicily	lbs. 7650	lbs. 4900	lbs. 9300	lbs. 11,070	lbs. 8647	
		The rind of the fruit.	....	Sicily	120 cwt.	165 cwt.	113 cwt.	218 cwt.	356 cwt.	
		The juice of the fruit.	....	Sicily	195 pipes	308 pipes.	611 pipes.	530 pipes.	727 pipes.	
	The Lime .... *Citrus limetta* (Risso).	The fruit preserved.	Asia	South America, West Indies, Greece.	....	....	....	....	....	Only imported preserved in sugar, consequently no correct weight can be obtained.
		The juice of the fruit.	....	....	40 pipes	45 pipes.	....	17 pipes.	30 pipes.	
	The Orange .... *Citrus Aurantium* (Risso).	The fruit	Supposed to be China.	Spain, Portugal, Italy and Sicily, the Azores.	packages 23,424	packages. 85,762	packages. 43,635	packages. 66,872	packages. 52,673	The packages average two bushels each.
				Brazil	bushels 30	bushels. 25	bushels. 40	bushels. 36	bushels. 42	
	The variety called Tangerine.	The fruit	....	Lisbon	21	12	15	30	25	
		Essential oil of the rind.	....	Sicily	160 lbs.	400 lbs.	220 lbs.	100 lbs.	300 lbs.	Used in perfumery.
		Essential oil of the flowers (*Oleum Neroli*).	....	France and Italy	250 lbs.	200 lbs.	150 lbs.	300 lbs.	330 lbs.	Used in perfumery.
		The wood.........	....	Italy.........	....	....	....	....	....	A few logs occasionally imported for cabinet work.
	The Shaddock......... *Citrus decumana* (Linn.).	The fruit	China	West Indies......	....	....	1200	600	1100	
	The Cumquat .... *Citrus olivæformis*.	The fruit	China .... (*Cumquat*.)	Canton.........	....	....	....	....	....	This delicious fruit is very frequently imported, but always as a preserve, so that the quantity cannot be ascertained.

	Triphasia aurantiola.								...	Only one importation of Lime-berries has taken place; it consisted of a dozen jars of the fruit preserved, imported in 1855.
Amyridaceæ.	Olibanum-tree ... *Boswellia serrata.*	The Gum-resin	India ...	Bombay ...	4 cases, 12 cwt.	...	...	6 cases, 18 cwt.	...	Used in making incense.
	The Myrrh-tree ... *Balsamodendrum Myrrha* (Nees).	The Gum-resin	Arabia Felix ...	E. Indies ...	2 cases, 6 cwt.	...	...	6 cases, 9 cwt.	...	Pharmaceutical.
					cubic feet	cubic feet	cubic feet	cubic feet	cubic feet	
Cedrelaceæ.	Mahogany ... *Swietenia mahagoni* (L.).	The timber ...	W. Indies and S. Indies.	Honduras ...	1,364,000	2,115,000	1,460,000	2,166,000	2,454,000	
				Gulf of Mexico	...	...	...	...	440,000	
				St. Domingo ...	1,297,000	1,318,000	1,420,000	1,320,000	962,000	
				Cuba ...	353,000	350,000	261,000	253,000	124,000	
	Cedar (false) ... *Cedrela odorata* (Linn.).	The timber ...	W. Indies and S. America.	Havana ...	336,000	220,000	82,000	277,000	53,000	
				Honduras ...	9,000	32,000	54,000	14,000	2,000	
Meliaceæ.	Carapa or Crab Oil ... *Carapa Guianensis* (Aubl.).	Expressed oil of the seeds.	Guiana ...	Demarara ...	...	...	...	...	...	Small quantities are frequently imported for private use, chiefly as a remedy for rheumatism.
Anacardiaceæ.	The Cashew-nut ... *Anacardium occidentale* (Linn.).	The nut ...	W. Indies ...	W. Indies ...	...	...	...	...	...	A few bushels are imported every year for private use as an edible fruit.
		The enlarged fruit-like receptacle.	W. Indies ...	W. Indies ...	...	...	...	...	...	This peculiar vegetable production is often imported in mixture with various fruits preserved in sugar, under the commercial name of Succades.
	The Marking-nut or Marany-nut. *Semecarpus anacardium* (Linn.).	The nut or rather the black resinous juice of the mesocarp.	E. Indies ...	E. Indies ...	...	bushels. 120	...	...	bushels. 130	These nuts are said to yield a valuable black varnish.
	Mastic or Mastich ... *Pistacia Lentiscus* (L.) & *P. atlantica* (Desfont.).	The resin ...	S. Europe, Barbary.	Smyrna ...	...	...	...	2 cwt.		

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Anacardiaceæ.	Pistachio-nut .... *Pistacia vera.*	The fruit	Greece	Greece	....	....	....	....	....	Small quantities imported for private use, chiefly by the Greeks.
Connaraceæ.	Zebra-wood........ *Omphalobium Lamberti* (*Schomburgk*).	The heart-wood.	Guiana and Brazil.	Brazil	planks. 281	....	planks. 835	planks. 549	planks. 119	A very beautiful furniture wood.
Simarubaceæ.	Bitter-wood or Quassia ...... *Picræna excelsa* (Lindl.).	The wood........	Surinam	Demarara........	tons. 146	....	....	tons. 230	....	This constitutes the principal portion of the Quassia-wood of European druggists.
Zygophyllaceæ.	Lignum-vitæ .... *Guaiacum officinale* (?) (Linn.).	The heart wood.	W. Indies........	St. Domingo, Cuba, Bahama.	tons. 1230	tons. 630	tons. 420	tons. 1000	tons. 380	Used principally by the block-makers and turners. The chips are used in medicine.
		The Gum-resin.	W. Indies........	Bahama	4 cwt.	3 cwt.	....	6 cwt.	....	Used only in pharmacy.
Linaceæ.	Flax .... *Linum usitatissimum* (Linn.).	The seed	Europe, Asia, and Northern Africa	Russia, Germany, N. America	bushels. 118,080	bushels. 117,832	bushels. 109,763	bushels. 159,408	bushels. 187,060	
				E. Indies	57,800	108,010	128,218	147,118	236,811	
		The fibres of the stalk.	....	Russia, Germany, Holland, France, Italy, Egypt, E. Indies, United States	308 tons.	420 tons.	312 tons.	467 tons.	550 tons.	
		Oil of the seed...	....	....	7 pipes.	16 pipes.	9 pipes.	18 pipes.	27 pipes.	
		The oil-cake or marc.	....	United States, Germany, Holland	375 tons.	440 tons.	700 tons.	620 tons.	680 tons.	

	Fagopyrum esculentum (Tourne.).			Holland.						
Polygonaceæ.	Rhubarb .... *Rheum palmatum* (Linn.).	The root	China	United States ...	20 chests, about 15 cwt.	....	....	....	....	Originally from China. The American tea-ships convey this and other China produce to the United States, which is sent thence to Europe if our markets are high.
Chenopodiaceæ.	Beet-root...................... *Beta vulgaris* (L.).	The seed	S. Europe	Italy and France	....	60 bushls.	....	....	....	This was doubtless the seed of the variety called Mangold Wurzel, imported for agricultural purposes, but imported as beet-root seed.
Piperaceæ.	Pepper (White)	The seed	Supposed to be India.	E. Indies	30 cwt.	....	36 cwt.	18 cwt.	96 cwt.	The white pepper of commerce is the seed separated from its pericarp. Black pepper is the entire berry.
	Pepper (Black) .... *Piper nigrum* (Linn.).	The dried berry..			1160 cwt.	3533 cwt.	2583 cwt.	5500 cwt.	3273 cwt.	
	Cubebs......................... *Cubeba officinalis* (Miquel).	The dried berry..	Java..............	India	3 bags, about 1 cwt.	....	....	....	16 bags, about 5 cwt.	
	Matico......................... *Artanthe elongata* (Miquel).	The dried leaves.	Peru.............. (*Matico.*)	Lima, Arica, and Islay.	6 cwt.	....	....	10 cwt.		
Lauraceæ.	Cinnamon .... *Cinnamomum zeylanicum* (Nees).	The bark	Ceylon and Java. (Cingalese, *Cacyn-nama*, Malayan, *Kaimanis.*)	Ceylon...........	....	10 bales, about 8 cwt.	....	....	....	Very little Cinnamon arrives at any port but London.
	Cassia (called Cassia lignea) *Cinnamomum Cassia* (Blume).	The bark	China .... (*Kwei Pe.*)	China	....	20 cwt.	41 cwt.	125 cwt.	63 cwt.	
		The dried flower-buds.	(*Kwei Tsze.*)	China	....	....	....	6 cwt.		

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Lauraceæ.	Indian Clove-bark .... *Cinnamomum Culilawan* (Blume).	The bark	Indian Islands...	Banca Straits ...	....	....	....	....	....	One small bundle was imported in 1855; but the quantity was not recorded. It was purchased by the captain of the importing vessel from some natives who boarded the ship in passing through the Straits.
	Camphor .... *Camphora officinarum* (Nees).	The stearoptine of the essential oil of the plant.	China, Japan, & Cochin China.	Canton............	....	....	....	....	250 cwt.	
	Brazilian Clove-bark .... *Dicypellium caryophyllatum*	The bark	Brazil	Para...............	12 cwt.	....	18 cwt.	....	....	Used in adulterating ground mixed spices.
	Sassafras Nuts.................. *Nectandra Puchury.*	The cotyledons of the seed.	Brazil	Para...............	6 cwt.	....	4 cwt.	8 cwt.	4 cwt.	Supposed to be used in flavouring Chocolate.
	Sassafras Wood .... *Sassafras officinale* (Nees).	The wood of the root.	N. America	United States ...	....	2 tons.	....	....	....	Pharmaceutical.
	Green-heart Wood .... *Nectandra Rodiæi* (Schomb.).	The timber	British Guiana...	Demerara	cubic ft. 83,000	cubic ft. 15,000	cubic ft. 6,000	cubic ft. 61,000	cubic ft. 25,000	Extensively used in ship-building and in making dock-gates, &c.
apilionaceæ.	Bean (Egyptian)............... *Faba vulgaris* (Moen.).	The seeds.........	Egypt	Alexandria	quarters. 18,372	quarters. 21,650	quarters. 12,682	quarters. 23,299	quarters. 260,950	
	Pea .... *Pisum sativum* (Linn.).	The seeds.........	S. Europe.........	Dantzic	2,760	4,063	1,470	3,691	5,070	
	Lentil .... *Ervum lens* (Linn.).	The seeds.........	Asia	Alexandria	563	....	....	437		
				Havre	3	....	....	....	4	
	Chick Pea .... *Cicer arietinum* (Linn.).	The seeds.........	Asia	Smyrna	....	....	210	....	70	

Leguminosæ. Suborder	Bean (Haricot) …………… *Phaseolus vulgaris* (Linn.), and its varieties, called *Haricots.*	The seeds………	India …………	United States, Europe.	30	17	5	23	16	
	Clover (Dutch) …………… *Trifolium repens* (L.).	The seeds………	Europe…………	Holland ………	130	115	127	216	370	
	Clover (American) ………… *Trifolium pennsylvanicum* (W.).	The seeds………	N. America ……	United States …	1,240	1,200	1,370	1,289	1,530	
	Lucerne …………………… *Medicago sativa* (L.).	The seeds………	Europe…………	Holland, Germany.	6 cwt.	…………	…………	13 cwt.	…………	Imported for sowing.
	Tares ………………………… *Vicia sativa* (L.).	The seeds………	Europe…………	Denmark………	50 qrs.	…………	…………	…………	30 qrs.	Imported for sowing.
	Fenugreek ………………… *Trigonella Fœnumgræcum* (L.).	The seeds………	Asia ……………	Trieste…………	…………	3 cwt.	…………	…………	…………	Used in Veterinary Pharmacy.
	Ground-nuts ……………… *Arachis hypogæa* (L.).	The seeds………	Africa …………	……………………	2 tons.	5 tons.	37 tons.	…………	15 tons.	For expressing oil.
	Liquorice…………………… *Glycyrrhiza glabra* (L.).	The root ………	S. Europe………	Hamburg………	12 cwt.	…………	…………	25 cwt.		
		The extract of the root …………	……………………	Italy……………	140 tons.	73 tons.	80 tons.	65 tons.	89 tons.	
	Tragacanth ………………… *Astragalus verus* (L.). *A. gummifer* (D.). *A. creticus.* *A. strobiliferus* (Lindl.).	The gum ………	Turkey in Asia and Persia.	Smyrna ………	…………	…………	…………	6 cwt.		
	Locust-tree ………………… *Robinia Pseudacacia* (L.).	The timber ……	N. America ……	Canada…………	…………	…………	…………	…………	…………	The only form in which this wood has been imported, is as ships' trenails, of which we receive vast numbers; but the bulk cannot be obtained.
	Rose-wood ………………… More than one species of *Trioptolomea.*	The timber ……	Brazil and Honduras.	Bahia ………… Rio …………… Honduras………	planks. 834 2630 12 tons.	planks. 4625 1874 34 tons.	planks. 3852 3426 34 tons.	planks. 5736 3083 233 tons.	planks. 3494 527 54 tons.	

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Leguminosæ. Suborder Papilionaceæ.	Sanders-wood *Pterocarpus Santalinus* (Linn.).	The wood	Coromandel and Ceylon. (*Chandama*).	E. Indies	8 tons.	....	10 tons.			
	East Indian Kino *Pterocarpus erinaceus* (Lamarck).	The gum	Malabar	Bombay	....	2 cwt.				
	Kessaree-flowers *Butea frondosa* (Roxburgh).	The dried flowers	E. Indies	Calcutta	....	3 cwt.	....	....	....	Imported for experiments in dyeing.
	Indigo *Indigofera tinctoria* (L.).	The colouring-matter of the plant.	India	E. Indies	chests. 760	chests. 310	chests. 530	chests. 1500	chests. 615	Chests contain from $2\frac{1}{4}$ to $2\frac{3}{4}$ cwt.
				S. America	serons. 2000	serons. 830	....	serons. 290	serons. 395	Serons contain from 1 cwt. to $1\frac{1}{2}$ cwt.
	Tonquin Bean *Dipteryx odorata* (W.).	The seeds	S. America	Brazil	....	cwt. 1800	....	5 cwt.	....	Used in perfumery.
	Prayer Liquorice *Abrus precatorius* (L.).	The seeds	W. Indies	W. & E. Indies	....	....	....	....	....	These ornamental seeds do not form a regular import; but small quantities are brought very frequently as curiosities and for making rosaries, &c.
...piniæ.	Senna *Cassia obovata* (DeCand.).	The leaves	Egypt and Nubia	....	46 bales, or about $2\frac{1}{2}$ tons.	....	....	187 packages, about 4 tons.		
	Cassia fistula *Cathartocarpus fistula* (Persoon).	The pulp of the legume.	E. Indies	E. Indies	....	....	6 chests, about 3 cwt.	....	4 chests, about 2 cwt.	
	False Cassia fistula *Cathartocarpus brasilianus* (Lam.).	The pulp of the legume.	S. America	New Granada	....	2 cwt.	....	....	....	Only once imported and offered for sale as *Cassia fistula*.
	Tamarinds *Tamarindus indica* (Linn.).	The pulp of the legume.	India	W. Indies	....	....	....	....	....	Tamarinds are largely imported, but only in the

										state of *preserves* in sugar; consequently the exact quantity cannot be obtained.
Leguminosæ. Suborder Cæsal-	Locust-fruit......... *Ceratonia siliqua.*	The legume	Southern Europe	The Levant	....	....	....	4 tons.	12 tons.	Imported for feeding cattle.
	Gum-Anime, or E. Indian Copal .... *Hymenæa verrucosa.*	The gum-resin...	E. Indies	Calcutta	....	113 cwt.	....	36 cwt.	45 cwt.	
	Balsam of Peru .... *Myrospermum* (species incertæ).	The balsam obtained by boiling the bark and wood in water.	Peru and Mexico (*Quinquino*).	New Granada ...	50 lbs.	....	30 lbs.			
	Balsam of Tolu .... *Myrospermum toluiferum* (Richard).	The balsam which exudes from incisions made in the bark.	Mountains of Tolu, Carthagena, St. Martha.	New Granada ...	40 lbs.	....	60 lbs.	....	10 lbs.	
	Myrospermum Pereiræ	The legumes ...	Carthagena	Carthagena	....	112 lbs.	....	....	....	Only once imported; these legumes contained a small quantity of balsam like the balsam of Tolu.
	Bar-wood and Cam-wood ... Both said to be derived from *Baphia nitida* (Loddiges).	The heart-wood	Sierra Leone ...	Sierra Leone ...	330 tons	318 tons.	420 tons.	410 tons.	480 tons.	Used only for dyeing.
	Sapan-wood......... *Cæsalpinia Sappan* (L.).	The wood.........	E. Indies	Bombay and Calcutta.	216 tons.	150 tons.	40 tons.	....	....	Used only for dyeing.
	Purple-wood, or Purple-heart *Copaifera pubiflora.*	The heart-wood.	Guiana.........	Demarara.........	....	2 tons.	5 tons.	....	7 tons.	Used chiefly for making ramrods for muskets.
	Balsam of Copaiba......... *Copaifera multijuga* (Hayne). *C. Langsdorfii* (Desfont.). *C. coriacea* (Mart.). *C. officinalis* (Linn.).	The oleo-resin, a natural exudation from the stems.	W. Indies and S. America.	Para .... Maranham ...	gallons. 1304	gallons. 1117	gallons. 1459	gallons. 1600	gallons. 1318	

Exogens (*continued*).

Nat. Order.	Producing Plants.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Leguminosæ. Suborder Cæsalpiniæ.	Divi-divi ...... *Cæsalpinia coriaria.*	The legume......	S. America...... (*Divi-divi.*)	Carthagena ... Savanilla ...... St. Domingo... Maracaibo, &c.	tons. 2000	tons. 2200	tons. 1800	tons. 2400	tons. 2050	Used only in tanning.
	Pi-pi ...... *Cæsalpinia papai.*	The legume......	S. America	S. America	....	....	....	....	....	Never imported alone; but it often comes much mixed with Divi-divi.
	Nicaragua-wood ...... *Cæsalpinia echinata.*	The heart-wood.	S. America ...... (*Brésil de St. Martha.*)	Rio de la Hache, Mazatlan and Lima.	4050	1450	4400	3650	1550	For dyeing only.
	Brazil-wood...... *Cæsalpinia crista* (L.).	The heart-wood.	S. America	Brazil	110	70	120	113	99	For dyeing only.
	Braziletto-wood ...... *Cæsalpinia brasiliensis* (L.).	The heart-wood.	S. America	Brazil	28	48	16	73	38	For dyeing only.
	Logwood ...... *Hæmatoxylon campechianum* (L.).	The heart-wood.	S. America, province of Yucatan.	Belize ...... Laguayra, &c.	15,700	11,100	14,100	18,700	20,000	For dyeing only.
Leguminosæ. Suborder Mimosæ.	Gum-Arabic ...... *Acacia vera* (Willdenow); *A. arabica* (Willd.); *A. gummifera* (Willd.); and other species.	The gum which exudes naturally from the bark.	Arabia and Africa, Africa and India, Barbary and Arabia.	Turkey...... E. Indies ...... Barbary	375	750	953	765	1285	
	Gum Senegal ...... *Acacia Senegal* (Willd.).	The gum which exudes naturally from the bark.	Africa and Arabia.	Senegal	3	....	$2\frac{1}{2}$			
	Mimosa Bark ...... *Acacia* (various species).	The bark	E. Indies and Africa.	Bombay	....	....	....	....	120	Used for tanning.
	Algarobilla ...... *Prosopis pallida* (?).	The dried legumes.	S. America	Valparaiso	....	....	....	....	30	Used for tanning.

Legu-Suborder	Mora-wood *Mora excelsa* (Schomb.).	The timber	Guiana	Demarara	cubic feet 3000	cubic feet 5000	cubic feet 2000	cubic feet 1000	cubic feet 5000	Used in shipbuilding and cabinet-makers' work.
	Go-go *Acacia abstergens?*	The fibrous part of the bark beaten out.	Manilla	Manilla	....	....	....	....	28 lbs.	Only once imported; it is used by ladies for cleansing the hair; it possesses saponaceous properties.
Drupaceæ.	Prunes *Prunus domestica.* Variety ζ. *Juliana.* French Plums Variety η. *Catharina.*	The drupe	Europe	France	120 tons.	113 tons.	140 tons.	200 tons.	170 tons.	
	Almond (Sweet) *Amygdalus communis* (L.).	The kernel	Barbary	Spain, Portugal, France, Italy & Sicily.	14 tons.	17 tons.	15 tons.	20 tons.	18 tons.	
	Almond (Bitter) Variety *amara.*	The kernel	Barbary							
	Peaches *Amygdalus persica* (L.).	The drupe	Persia	United States	....	....	....	....	....	Considerable quantities of Peaches are imported, both dried and preserved in hermetically sealed tins, but the quantity cannot be ascertained.
Pomaceæ.	The Apple *Pyrus Malus* (L.).	The fruit	Europe and Asia.	America (U. S.), France, Channel Islands, &c.	bushels. 12,000	bushels. 8000	bushels. 15,000	bushels. 14,000	bushels. 18,000	The greater portion comes from the Channel Islands and the United States.
		The fruit dried.	....	America & France	72	115	110	300	295	From the latter country in barrels, from Jersey and Guernsey in bulk.
	The Pear *Pyrus communis* (L.).	The fruit	Europe and Asia.	France & America	....	....	....	....	....	Pears are only imported preserved in sugar and dried; therefore the exact quantity cannot be ascertained. Probably it does not exceed 20 bushels annually.

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Pomaceæ.	The Loquat .... *Eriobotrya japonica* (Lindl.).	The fruit	Japan. (Called *Nespres* in the Azores.)	From the Azores.	6	....	....	....	15	The fruit is only rarely imported, and is hardly saleable in this country.
	The Azarole .... *Cratægus azarolus* (L.).	The fruit	S. Europe ...... (*Azarola.*)	Spain	....	....	....	....	A few lbs. only.	Only once imported, preserved in sugar.
Rosaceæ.	The Rose .... *Rosa damascena* (Mil.).	Its essential oil or Otto of Roses.	The Levant	Turkey........	....	4 lbs.	....	2 lbs.	5 lbs.	
	Kussoo or Koosoo .... *Brayera anthelmintica* (Kunth).	The flowers	Abyssinia........ (*Koosoo.*)	Egypt	....	....	....	....	50 lbs.	Medicinal; used as a vermifuge only.
Ulmaceæ.	The Elm .... *Ulmus americana* (Ph.), and probably other species.	The timber	Canada & United States.	Canada and the United States.	logs. 3110	logs. 4053	logs. 4480	logs. 4443	logs. 4894	In all about 152·500 cubic feet.
Rhamnaceæ.	Yellow Berries .... *Rhamnus infectorius* (L.).	The berries gathered unripe and dried.	S. of Europe.	Constantinople, Smyrna, Trieste, Marseilles.	63 tons.	57 tons.	18 tons.	43 tons.	60 tons.	For dyeing only.
Sapotaceæ.	Gutta-percha .... *Isonandra Gutta* (Hooker).	The hardened juice.	Singapore, Borneo and other Malay Islands. (*Gutta Percha.*)	Singapore.	27 tons.	30 tons.	55 tons.	102 tons.	87 tons.	
Styraceæ.	Gum Benjamin or Benzoin... *Styrax Benzoin.*	The gum-resin.	Sumatra, Borneo, Siam and Java.	Singapore	$2\frac{1}{2}$ cwt.	13 cwt.	6 cwt.	9 cwt.	8 cwt.	Pharmaceutical.
naceæ.	Ebony (African) .... Tree unknown.	The heart-wood.	Western Africa.	Sierra Leone ...	50 tons.	101 tons.	300 tons.	....	....	Nothing being really known of the tree which produces this wood, it is placed provisionally in this Natural Order.

Ebe-	Ebony (E. Indian or Ceylon). *Diospyrus ebenaster.*	The heart-wood.	Ceylon...........	Ceylon and E. Indies.	30 tons.	200 tons.	220 tons.	17 tons.		
Aquifo-liaceæ.	Paraguay Tea .. .. Yerba do Maté or Paraguay Holly. *Ilex Paraguayensis* (Hilaire).	The leaves and young twigs.	Brazil and Paraguay. (*Yerba* of the settlers.)	Brazil	....	....	....	....	....	The Paraguay tea comes very frequently, but only in small quantities and not for commercial purposes.
Apocy-naceæ.	Nerium seeds .... *Wrightia antidysenterica* (R. Br.).	The seeds.........	E. Indies	E. Indies	....	....	2 cwt.	....	....	Imported experimentally as a medicinal product; suggested also for brewers' purposes.
Loga-niaceæ.	Nux Vomica .... *Strychnos Nux vomica* (L.).	The seeds.........	E. Indies	Bombay and Calcutta.	tons. cwt. 2 2	7 tons.	9 tons.	93 bags, about 1½ ton.	617 bags, about 11 tons.	
Gentia-naceæ.	Gentian .... *Gentiana lutea* (L.).	The root	The Alpine parts of Europe.	Hamburg and Marseilles.	32 cwt.	47 cwt.	38 cwt.	63 cwt.	87 cwt.	
Oleaceæ.	The Olive .... *Olea europæa* (L.).	The unriped fruit pickled.	S. of Europe ...	France, Spain, Portugal, Italy, Greece.	gallons. 520	gallons. 430	gallons. 612	gallons. 340	gallons. 660	
		The oil obtained from the ripe fruit.	....	France, Italy, Spain, and Portugal.	tuns. 5100	tuns. 3600	tuns. 4000	tuns. 4330	tuns. 10,100	Tun of 250 gallons.
		The seeds.........	....	Palestine	....	....	....	....	....	Rosaries of these seeds are often imported.
		The wood.........	....	Palestine	....	....	....	....	....	Articles made of olive wood such as rosaries, paper-knives, writing cases, &c., are also very frequently imported, chiefly by tourists.
	Ash (Quebec) .... *Fraxinus excelsior* (Willdenow).	The timber	N. America	Canada............	cubic ft. 17,000	cubic ft. 42,000	cubic ft. 28,000	cubic ft. 17,000	cubic ft. 17,000	
	Manna Ash .... *Fraxinus Ornus* (Linn.).	The Manna, an exudation from the branches.	S. Europe	Palermo	18 cwt.	....	....	25 cwt.	....	Pharmaceutical.

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Solanaceæ.	Tobacco .... *Nicotiana Tabacum* (L.).	The leaves	Tropical America.	United States ... Paraguay	tons. 5302 60	tons. 7338 49	tons. 7117 121	tons. 7121 50	tons. 6123 64	
	Greek and Turkish Tobacco. *N. rustica* (L.).	The leaves and flower-stalks.	Asia? & Europe.	Turkey, Greece.	130	117	235	440	99	
	Chinese Tobacco............... *N. chinensis* (Fisch.).	The leaves	China	China	12 cwt.					
	Capsicum pods ...., *Capsicum amnium.*	The ripe fruit ...	E. Indies	Calcutta and Bombay.	2 tons.	$4\frac{1}{2}$ tons.	3 tons	6 tons.	7 tons.	
	Pods of the Cherry Pepper *Capsicum cerasiforme.* Bell Pepper.................. *C. grossum.* Yellow Capsicum............ *C. luteum*; and Bird Pepper..................	Ripe and unripe fruit.	E. and W. Indies, and Africa.	E. and W. Indies, S. America, and Africa.	....	....	....	....	....	A considerable quantity of these fruits is continually arriving in a pickled state, but the quantity is not ascertainable.
	Tomatoes........................ *Lycopersicum esculentum* (Duval).	The ripe fruit ...	S. America	W. and E. Indies, America and Europe.	....	....	....	....	....	Considerable quantities are constantly arriving, chiefly in the form of sauce; a few fresh fruits are received from Portugal and the United States.
	Potatoe .... *Solanum tuberosum* (L.).	The tubers	Peru...............	France and Portugal.	313 tons.	360 tons.	412 tons.	500 tons.	415 tons.	Chiefly imported early in the spring, to supply the markets with "new potatoes."
Asclepiadaceæ.	Indian Sarsaparilla.......... *Hemidesmus indicus* (R. Br.).	The roots.........	E. Indies. (*Unun tamul*, Hindoo and Bengalese; *Nannari*, Tamul.)	E. Indies	....	2 bales or about 5 cwt.	....	....	....	Used only in pharmacy as a substitute for Sarsaparilla; it contains Smilaspennic acid.

Convolvulaceæ.	Jalap .... *Exogonium purga* (Bentham).	The tubers or roots.	Mexico..........	Vera Cruz	2 cwt.	....	5 cwt.	$2\frac{1}{2}$ cwt.	4 cwt.	Pharmaceutical.
	Scammony .... *Convolvulus Scammonia* (Linn.).	The gummy resinous juice of the root.	Greece and the Levant.	Smyrna	$\frac{1}{2}$ cwt.	$1\frac{3}{4}$ cwt.	....	3 cwt.	$3\frac{1}{2}$ cwt.	
Boraginaceæ.	Alkanet root .... *Anchusa tinctoria* (L.).	The root	....	....	....	5 cwt.	3 cwt.	....	....	Used for colouring oil and staining wood.
Labiatæ.	Lavender .... *Lavendula vera* (De Cand.).	The essential oil of the flowers.	S. of Europe ...	France	20 lbs.	....	17 lbs.	16 lbs.	24 lbs.	
	Peppermint .... *Mentha piperita* (Linn.).	The essential oil of the herb.	Europe...........	America (N.) ...	400 lbs.	230 lbs.	362 lbs.	519 lbs.	420 lbs.	
	Wild Marjoram .... *Origanum vulgare* (Linn.).	The essential oil of the herb.	Europe and Asia.	France	150 lbs.	70 lbs.	....	215 lbs.	200 lbs.	
	Patchouly .... *Pogostemon Patchouli.*	The leaves	E. Indies .... (*Puchu-pat.*)	E. Indies	....	....	....	16 cwt.	....	Used only in perfumery.
Verbenaceæ.	Teak............................ *Tectona grandis* (Linn.).	The timber	E. Indies	E. Indies	cubic feet 120,000	cubic feet 118,000	cubic feet 38,000	cubic feet 77,000	cubic feet 192,000	Used chiefly for ship-building.
Crescentiaceæ.	Calabash .... *Crescentia Cujete* (L.).	The fruit	Tropical America	S. America and the W. Indies.	....	....	....	....	....	The calabash, though not forming an article of commercial importance, is continually imported in the form of bowls and other Indian curiosities.
Pedaliaceæ.	Sesamum or Ginglie .... *Sesamum orientale* (W.).	The seed	E. Indies.........	E. Indies	430 qrs.	600 qrs.	537 qrs.	308 qrs.	1206 qrs.	Used only for expressing oil.
		Expressed oil of the seed.	....	E. Indies	....	....	2500 gall.	1575 gall.		
Lobeliaceæ.	Lobelia .... *Lobelia syphilitica* (L.).	The dried herb.	Virginia	N. America	10 lbs.	50 lbs.	....	....	....	Imported for certain empirics called Coffinites or herb doctors.

Exogens (*continued*).

Nat. Order.	Producing Plants.	Part employed.	Native Country and Name.	Whence Imported.	Imports, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Compositæ.	Safflower .... *Carthamus tinctorius.*	The dried petals of the flowers.	E. Indies and Egypt.	E. Indies	184 cwt.	....	570 cwt.	1089 cwt.	492 cwt.	
				Egypt	....	8 cwt.				
		The seed	....	Bombay	120 bush.	....	....	215 bush.	460 bush.	
		Oil of the seed...	....	Odessa	....	....	....	gallons. 2300		
	Niger-seed .... *Guizotea oleifera.*	The seed	....	Bombay	bushels. 1200	bushels. 1470	bushels. 2040	bushels. 2000	bushels. 1450	Used for expressing oil.
	Chicory .... *Cichorium Intybus* (L.).	The root	Europe........	Hamburg and Holland.	170 tons.	178 tons.	200 tons.	180 tons.	270 tons.	
	Arnica .... *Arnica montana* (Linn.).	The flowers	....	....	....	....	....	....	12 lbs.	Only one importation, by a homœopathic druggist.
		The leaves	Europe........	France	....	....	....	....	10 lbs.	
		The root	....	....	....	....	....	....	5 lbs.	
	Worm-seed .... *Artemisia* (var. species).	The flowers and pedicels.	Barbary	Mogadore	6 cwt.	....	....	4 cwt.		
	Chamomile .... *Anthemis nobilis* (Linn.).	The flowers	Europe........	Hamburg........	....	....	30 cwt.	....	45 cwt.	German growth.
Combretaceæ.	Myrobalanus .... *Terminalia chebula.*	The fruit dried...	E. Indies	Bombay	680 tons.	489 tons.	704 tons.	713 tons.	712 tons.	
	The Clove .... *Caryophyllus aromaticus* (Linn.).	The flower-bud dried.	Molucca Islands.	E. Indies	....	....	70 cwt.	221 cwt.	375 cwt.	
	Pimento or Allspice .... *Eugenia Pimento* (De Cand.).	The ripe berries..	W. Indies........	W. Indies........	93 tons.	133 tons.	32 tons.	140 tons.	54 tons.	
ceæ.	The Guava .... *Psidium pyriferum.*	The ripe fruit ...	W. Indies and S. America.	W. and E. Indies and S. America.	....	....	....	....	....	The guava is imported in considerable quantities in

Myrt	The Pomegranate .... *Punica Granatum* (Linn.).	The ripe fruit ...	....	Portugal and Spain.	....	....	packages 80, about 120 bush.			the form of sweet preserves; but the exact quantity is not ascertainable.
		The rind of the fruit.	....	Morocco	4 cwt.	....	2 cwt.	$2\frac{1}{2}$ cwt.	....	Used as an astringent in pharmacy.
		The dried flowers	....	Italy...............	....	....	....	....	....	Only a few pounds were imported in 1852 for medicinal purposes.
Lecythidaceæ.	Brazil or Para Nut .... *Bertholetia excelsa.*	The kernels......	Brazil	Brazil	bushels. 16,772	bushels. 14,600	bushels. 18,650	bushels. 25,000	bushels. 26,700	Used only as edible fruit.
	Sapucaia Nut ... . *Lecythis Ollaria.*	The kernels......	Brazil	Brazil	30	10	....	16	5	Edible.
Cactaceæ.	Prickly Pear .... *Opuntia vulgaris.*	The ripe fruit ...	S. America	Palermo	....	....	20 boxes.	....	....	Edible.
Vacciniaceæ.	Cranberry .... *Oxycoccus macrocarpa.*	The ripe fruit ...	Newfoundland...	Newfoundland...	120 gall.	87 gall.	156 gall.	300 gall.	310 gall.	Edible.
Rubiaceæ (*Jussieu*).	Peruvian Bark................. *Cinchona angustifolia* (Ruiz and Pavon); *C. cordifolia* (Weddell); *C. ovata* (idem); and probably other species.	The dried bark...	Peru...............	Lima .... Bolivia......... Carthagena ... Bogota, &c....	139 tons.	126 tons.	160 tons.	133 tons.	147 tons.	
	Coffee .... *Coffæa arabica* (Linn.).	The seeds.........	Arabia and Ethiopia.	E. & W. Indies Ceylon .... Brazil	2466 „	1806 „	2138 „	3298 „	3158 „	
	Ipecacuanha .... *Cephaëlis Ipecacuanha* (Richard).	The root	Brazil	Brazil	6 cwt.	....	....	4 cwt.	8 cwt.	Pharmaceutical.

Exogens (*continued*).

Nat. Order.	Producing Plant.	Part employed.	Native Country and Name.	Whence imported.	Imp rts, 1851.	Imports, 1852.	Imports, 1853.	Imports, 1854.	Imports, 1855.	Observations.
Rubiaceæ (*Jussieu*).	Madder .... *Rubia tinctoria* (Linn.).	The root, whole and ground.	Asia and Europe.	E. Indies ...... Turkey......... Italy............ Holland ...... France	tons. 11,275	tons. 10,600	tons. 12,425	tons. 10,000	tons. 10,800	For dyeing only.
		Garancine, a preparation of Madder	....	....	30	56	60	68	61	For dyeing only.
	Munjeet .... *Rubia munjista* (Roxb.).	The root	E. Indies	E. Indies	4	10	7	3	11	For dyeing only.
Umbelliferæ.	Caraway .... *Carum Carui* (Linn.).	The fruit (called the seed).	Caria	Rotterdam ... Hamburg......	32 bush.	509 bush.	270 bush.	460 bush.	612 bush.	
	Coriander .... *Coriandrum sativum* (Linn.).	The fruit (called the seed).	S. of Europe ...	Italy	....	20 „	....	36 „		
	Aniseed or Anise............... *Pimpinella Anisum* (Linn.).	The fruit (called the seed).	Egypt and Scio...	Bordeaux...... Naples .... Malta .... Constantinople	526 „	711 „	726 „	645 „	516 „	
	Cumin .... *Cuminum Cyminum* (Lin.).	The fruit (called the seed).	Egypt and Ethiopia.	Marseilles ... Smyrna	190 „	410 „	316 „	406 „	260 „	
	Angelica .... *Archangelica officinalis* (Linn.).	The root	N. of Europe ...	St. Petersburg...	....	2 cwt.	....	....	....	Used in pharmacy.
	Assafœtida .... *Narthex Assafœtida* (Falconer).	The gum-resin...	Saristan, Affghanistan, Punjaub.	Bombay	10 cwt.	....	27 cwt.	....	....	Used in pharmacy.
	Ammoniacum .... *Dorema ammoniacum* (Don).	The gum-resin...	Persia .... (*Derukht ushak.*)	Bombay	....	....	3 cwt.	....	....	Used in pharmacy.

Araliaceæ.	Rice-paper *Aralia papyrifera* (Hook.).	The pith of the stem.	China and the Indian Archipelago.	China						No regular importations take place; but almost every ship from China brings presents of drawings on this beautiful material, and occasionally a small quantity is brought for making artificial flowers.
Santalaceæ.	Sandal Wood *Santalum album* (Linn.).	The wood	E. Indies	E. Indies						Sandal wood is only imported in a manufactured state in the form of work-boxes, desks, and other small ornamental articles.
Aristolochiaceæ.	Snake-root *Aristolochia serpentaria* (Linn.).	The root	N. America	N. America		3 cwt.			5 cwt.	Used only in pharmacy.
	Huaco or Guaco *Aristolochia anguicida*? (?).	The whole plant.	S. America, Carthagena. (*Guaco* or *Huaco*)	Carthagena			2 cwt.			One small bale only, imported for the French government. It is the celebrated Snake-poison antidote.

Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom. By ANDREW HENDERSON, *F.S.A. & A.I.C.E.*

THE importance of this subject has already brought it before the British Association, both at Hull and at Liverpool. In the latter case, a Committee reported, through their chairman, Major-General Chesney, as follows:—"It is manifest that, however zealous the existing Societies may be (the Life-boat and the Shipwrecked Fishermen's), neither they nor the Admiralty possess the necessary funds for this purpose; these can only be adequately provided by Parliament; but in order to effect this object, judiciously and economically, it appears most desirable that, as a preliminary step, the British Association should recommend the Government to institute such experiments as will enable the public to form a judgment on a subject which is beset with difficulties."

The papers and plans were published in p. 327 of the Report of the Liverpool Meeting of the Association in 1854. At that Meeting it was resolved, "That Mr. Henderson and Colonel Chesney be a committee for the purpose of collecting the statistics of the design, arrangements and dimensions of Life-boats." A preliminary report was made by Mr. Henderson, but not printed in the volume of the Transactions of Glasgow in 1855.

The General Meeting of the Association at that place appointed a committee, "consisting of Mr. Andrew Henderson, Major-General Chesney, Sir Edward Belcher, Mr. John Wood, Mr. James R. Napier, Sir William Jardine, Bart., Mr. W. Ramsay, and Mr. James Thompson, who were requested to continue these investigations as to the statistics and condition of Life-boats and Fishing-boats; as to the principles on which Life-boats should be constructed; the essential conditions of their successful use; and the means of establishing them round the coasts of the British Isles, and on board British ships."

Difficulties were still found to exist in the want of funds for experiments, in the members residing in distant parts of the country, and from their having no establishment for the record of papers and models of the various life-boats and fishing-boats in use or improvements proposed. The latter difficulty was expected to be met by the resolution of the Association at Liverpool in 1854:—"*That it was expedient, for the advancement of naval architecture, that a portion of the intended Museum at Liverpool should be appropriated to that purpose.*" The Museum in question was only then proposed to be built by Mr. William Brown, M.P., whose impatience of delay has been shown by his generously erecting the Museum at his own expense, the first stone being laid in the winter of 1856.

Meantime Mr. Arthur Anderson, Chairman of the Crystal Palace Company, having obligingly placed the naval gallery of the Palace at the disposal of the Committee, for the exhibition of ships, life-boats, and fishing-boats, that difficulty may be considered removed for the future.

At the meeting at Cheltenham, in 1856, it was resolved, that a Committee, consisting of Mr. A. Henderson, Mr. A. Anderson, Captain Sir E. Belcher, R.N., Mr. J. R. Napier, Mr. J. Thompson, C.E., Mr. H. Ramsay, C.E., Captain J. P. Owen, and Sir W. Jardine, Bart., be requested to continue the investigation as to the statistics and condition of life-boats and fishing-boats; as to the principles on which such boats should be constructed, the essential conditions of their successful use, and the manner of establishing them round the coasts; with £5 at their disposal for the purpose.

Unfortunately, these difficulties still exist; the only aid afforded by Go-

vernment being contributions from the Mercantile Marine Fund, by the Board of Trade, awarded for saving life, payment to the crews of life-boats, and assistance in launching them. The Board have also deputed Commander Robertson to visit the stations and report upon the state of the life-boats and rockets established on the coast. From a published return, obligingly furnished by order of the Board, it appears from the Wreck Chart, which shows by spots and crosses the position of the wrecks and damaged vessels on the coast of the United Kingdom, amounting to 987 casualties in the year 1854, that the loss of life, so far as can be ascertained, amounted to 1549 lives. A similar return for the year ending the 31st December, 1855, has been presented by the Board of Trade to Parliament, and published, from which it appears that no less than 1141 wrecks occurred on the coasts of the United Kingdom in that year; about one-half of that number took place on the east coast of Great Britain. The loss of life from shipwreck during the same period was, however, comparatively small, being only 469, or less than one-third of the preceding year, and considerably less than in any former year of which we have a record. The number of lives saved from wrecked vessels was,—

By luggers and small craft	439
By assistance from shore by mortar-apparatus, &c.	399
By ships and steam-vessels	290
By life-boats	251
By individual exertion	9
Total	1388

STATISTICAL STATEMENT OF LIFE-BOATS AND FISHING-BOATS ON THE COASTS OF THE UNITED KINGDOM, 1855.

WEST COASTS OF ENGLAND AND WALES.

Station.	No. of Boats.	Build, materials, and arrangements.
Whitehaven	1	Peake's New.
Lytham	1	Beaching's, replaced by Peake's.
Southport	1	Good.
Liverpool	5	Port of Liverpool.
Rhyl	1	Beaching's model altered; to be replaced by Tubular Boat.
Penmon	1	In good and efficient state.
Llanddowyn	1	Anglesea Life-boat Association.
Comlyn	1	Anglesea Life-boat Association.
Holyhead	1	Anglesea Life-boat Association.
Rhoscolyn	1	At Holyhead, under repair.
Moelfre	1	In good condition.
Barmouth	2	In good condition.
Port Madoc	1	In good and efficient condition.
Barmouth	1	In good and efficient condition.
Aberdovey	1	In doubtful condition — scarcely ever ordered.
Aberystwith	1	In builder's yard store—is useless.
Cardigan	1	In good and efficient condition.
Fishguard	1	Good and efficient.
Tenby	1	In good condition; about to be sent to London for alterations.
Llanelly	1	As Government vessel, in good and efficient condition; manned by the pilots.
Swansea	1	Useless; lying in a timber yard.
Burnham	1	In very indifferent condition — never launched.

SOUTHERN COAST OF ENGLAND.

Station.	No. of Boats.	Build, materials, and arrangements.
Ilfracombe	1	In good and efficient condition.
Appledore	3	All efficient and in good order. (Wallis, after Peake.)
Budehaven	1	Complete and efficient.
Padstow	1	In Coast Guard House; bad boat, out of repair; a new one required.
St. Ives	1	In a timber yard; useless in every way.
Sennit Cove, Land's End	1	Efficient, and in good condition.
Penzance	1	Just built; not equipped; not much exertion used to get her ready.
Teignmouth	1	In good condition, but about to be sent to London for alterations.
Lyme Regis	1	Complete and most efficient.
Worthing	1	Complete and most efficient.
Shoreham	1	In good condition and serviceable.
Brighton	1	In fair condition; allowed to be used by anybody.
Newhaven	1	In serviceable condition.
Eastbourne	1	In serviceable condition.
Rye	1	In fair condition only.
Dungeness	1	Complete and most efficient.
Dover	1	In London undergoing alterations
Ramsgate	1	Complete and most efficient.
Broadstairs	2	In fair condition.

EAST COAST OF ENGLAND.

Station.	No. of Boats.	Build, materials, and arrangements.
Harwich	1	Has not been in the water for 4 years.
Aldborough	1	Good.
Thorpeness	1	Good.
Southwold	2	B. One (Mr. Beechney's) good; but no confidence in the other.
Pakefield	1	Good.
Lowestoft	1	In good condition.
Yarmouth	2	One under repair; the other small, but good.
Cromer	2	Clumsy.
Wells	0	A life-boat formerly here; found her removed to Baeton—still there.
Skegness	1	Good.
Spurn Port, Hull	1	New.
Bridlington	1	Good.
Scarborough	2	One (Mr. Peake's) new.
Whitby	2	Good.
Robin Hood's Bay	1	Good; but boat-house bad.
Stockton	4	Seem to be good.
Hartlepool, West	1	Good; and one building.
Hartlepool, North	3	Good; one new.
Sunderland	3	Good.
Shields, North	1	Good; one building for Tynemouth.
Shields, South	2	Good.
Blyth	2	Good; one Mr. Peake's.

COASTS OF SCOTLAND.

Station, and name of Designer and Builder.	No. of Men.	No. of Boats.		By whom established, build, material, and arrangements.
Berwick, Peake............	—	L.	1	Life-boat Institution; cost, £156.
District of Leitham,				
Eyemouth Fishing Sta.	2117	F.	579	Usual Fishing-boat.
St. Andrews	—	L.	1	Good.
Anstruther District	2099		—	
Fishing Stations	—	F.	500	Fishing-boat.
Dundee	—	L.	2	Good.
Arbroath	—	L.	1	
Montrose	—	L.	1	
Stonehaven	—	L.	1	
Aberdeen	—	L.	1	
Peterhead District	2091	F.	656	Usual Aberdeen boat.
37 Fishing Stations	140		—	
Fraserburgh District......	1467	F.	439	The Fraserburgh boat.
7 Fishing Stations				
Banff District	2853	F.	776	Usual Buckie boat.
12 Fishing Stations				
Kingshorn to Lyster Dis.	3802	F.	1049	
Wick District	3227	F.	853	
Orkney Isles................	2471	F.	608	Small Fishing-boat.
Shetland Isles	3162	F.	665	Do. Norway yawl.
Stornoway & Broom Dis.	4298	F.	988	
Shielding & Skye Dis....	3674	F.	1058	
Inverary	3189	F.	1062	
Rothsay and Greenock...	3524	F.	1193	Short sloop.
Ardrossan, Peake	—	L.	1	Local Committee.
Irvine........................	—	L.	1	Old.
Ayr............................	—	L.	1	Old and bad.
Isle of Man	2372	F.	487	

During 1856, further inquiries were prosecuted through circulars sent to different parts of the coast, giving the particulars of the life-boats more in detail, in which every assistance was afforded by the Royal National Life-Boat Institution, and by the Marine department of the Board of Trade, so far as the examination of the official returns made to the Board as to the condition of life-boats on the coast, and the other information now annually published of wrecks and casualties on the coasts of the United Kingdom.

This is a most valuable and useful document, comprising a statement of the number of lives lost and saved, the amount granted out of the Mercantile Marine Fund as rewards for the salvage of life, and contributions towards the maintenance of life-boats; the former being £1384, and the latter £962 last year. There is also a *précis* of the special inquiries instituted into the causes of wrecks and casualties, abstracts of the whole being given in twenty-five tables, affording a comparative and statistical record of wrecks and casualties, further elucidated by the Wreck Chart now published annually, copies of which may be had from the Queen's printers, and are republished in the 'Lifeboat Journal' of the National Life-Boat Institution, to which I would earnestly recommend all interested to become subscribers.

It will be observed by the Wreck Chart, that there are few wrecks on the coast of Scotland; and although there are only eleven life-boats, Scotland is provided with as good means of saving life as any part of the United Kingdom, seeing that by the report of the Edinburgh Board of Fisheries, December 1854, there were stationed on the coasts of Scotland, Shetland, Orkney, and Isle of Man, 10,891 fishing-boats, manned by 40,359 fishermen, hundreds of which could be readily converted into efficient life-boats, with experienced crews.

There must be many stations on our coasts requiring life-boats, as will be seen by the Wreck Chart, which shows by spots and crosses the position of the wrecks and damaged vessels on the coasts of the United Kingdom to have amounted to 987 casualties in the year 1854;—that of these, 431 were total wrecks, and 53 vessels sunk by collision, making the number totally lost 484. Of vessels stranded and damaged, so as to be obliged to discharge their cargoes, there were 462; those by collision, 41, amounting to 503, making the total number of wrecks and casualties 987 vessels. The loss of life, as far as can be ascertained, amounted to 1549 lives in 1854, being 560 more than in the previous year, while the number of vessels lost was 155 more than in 1853.

The tonnage of these fishing-boats amounts to 72,414 tons, and the total value of boats, nets and lines to £587,420,—an aggregate of fishermen, tonnage and capital well deserving the attention of the Commissioners for the British Fisheries, as well as the aid of Her Majesty's Government.

This was afforded when Captain Washington, R.N., was ordered to report on the loss of life and damage sustained by fishing-boats in the gale of the 19th of August, 1848. This Report was published July 1849 (pp. 579), giving the statistics of the Fishery and Boats;—the Secretary, the Honourable B. F. Primrose, stating the desire of the Commissioners to aid in establishing trial boats in the Fishery Districts, and a relative comparison of the different boats. The Report contains the drawings of sixteen boats, with two designed by Mr. Peake, of Woolwich Dockyard, of improved form, with the opinion of practical boat-builders on the alterations proposed.

There was also a tabular statement of the dimensions and particulars of thirty boats, affording information to enable fishermen to select a boat that would meet the requirements of each locality; but as no attempt was made to build a trial fishing-boat, or other improvement, it is doubtful if much good has been effected in improving our fishing-boats; and only at two places have I found that the Report was at all known to the fishermen, while a few weeks' observation of a trial boat might have saved some of the 124 boats and 100 lives.

AS TO LIFE-BOATS.

In 1849, the Tyne Life-boat upset and drowned 20 pilots, which led the Duke of Northumberland to offer a prize of 100 guineas for the best model of a Life-boat. Captain Washington, R.N., and a Committee of Naval Officers and Surveyors, having considered the merits of 280 models and plans, awarded the prize to Mr. Beeching's model, accompanying it by a report. His Grace the Duke of Northumberland gratuitously circulated thirteen hundred copies of this Report, accompanied by plans, drawings, and detailed descriptions of the best life-boats—including those of a 30-feet boat, designed by Mr. J. Peake, "in which, profiting by the experience gained in the examination of the models, all the best qualities of a life-boat should be combined." The Lords of the Admiralty ordered that a life-boat according to those lines should be built in Her Majesty's Dockyard, Woolwich.

A catalogue or tabular return was furnished of the 280 models and plans competing for the prize, giving their dimensions, weight and cost. Thirty are described in detail; and then published plans and sections of the internal life-boat arrangements and disposition of buoyancy of thirteen boats, commencing with Beeching's Prize Model, which is stated to be ballasted with two tons of water and half-a-ton of iron keel, by means of which, and raised air-cases in bow and stern, it was stated she would right herself when upset.

There are other life-boat constructors who have spent much time and money in completing their inventions, without being able to bring them into

practical use, particularly the Rev. J. S. Berthon, who proposed the Fareham or Collapsing Life-boat. Although his boats have been in use for three years, he has only succeeded in building two boats for Her Majesty's Navy, not yet placed in service. Mr. Clarkson has had a boat in use for some time on the coast, constructed of a mixture of cork and india-rubber. Mr. Asley has patented a life-boat of peculiar form, having a hollow bottom, of which a model is exhibited, and lies now at Dover. The fishermen's life-boat before mentioned, built by myself, has been tried on the Mersey for two years past, in the hope of establishing her on the neighbouring coast.

In collecting the statistics of the design, arrangements, and dimensions of life-boats, at the desire of the British Association, I have availed myself of the before-mentioned Report of Captain Washington on Fishing-boats, in 1849, and of the plans and tabular statements of dimensions in the Northumberland Report on Life-boats, in 1851, and have continued these to 1853, with additional particulars, defining the displacement, bulk, space, resistance, and form, exemplified by diagrams of midship sections, as affording a closer analysis of their relative sizes, proportions, properties and capacity, and their comparative efficiency.

TABULAR RETURN OF FISHING-BOATS AND LIFE-BOATS.—COMPARATIVE PLAN OF MIDSHIP SECTIONS.

The Tabular Return is adopted as the most convenient mode of recording the design, arrangements, and dimensions of the life-boats and fishing-boats on our coasts, adding, for comparison, the particulars of Chinese, Bombay, Malay, Arab, and American fishing-boats, as to life-boats. Several of the most efficient of the original life-boats, as well as those of improved construction and recent design, are included in the Tabular Return, so as to afford a comparative analysis of their respective properties, which are further explained in the remarks on each boat; some by printed diagrams, and others by lithographed working drawings and printed descriptions, 500 copies of which have been gratuitously circulated at the meetings of the Association at Liverpool, Glasgow, and Cheltenham, and may now be obtained by gentlemen interested in the subject, in the hope of collecting further information as to the boats actually in use on the coasts of England and Ireland. For the coasts of Scotland, information may be obtained from the Annual Report of the Edinburgh Board of Fisheries, who, with an organized staff of fishery officers on the coast, and the able supervision of the Secretary, Mr. Primrose, have done much to increase the fisheries and improve the harbours on the coast. These tabular returns are made separately, for the original life-boats and designs, and for forming comparisons with the other returns of the life-boats and fishing-boats on the coast of Scotland, on the east coast of England, on the southern coasts of England and Wales, and on the coast of Ireland. The Annual Report of the Commissioners of the Irish Fisheries is also published.

In stating the peculiarities and services, or describing the boats, they will be referred to by the initial letteror the number of the line on each separate return.

A reference to the Statistical Statement will show the position of the life-boats and fishing-boats on the coast in 1855; the Tabular Return will show the particulars of those established in 1856; while, by inspection of the Wreck Chart, it will be seen where the life-boats are wanted, or are more urgently required; the number and description of fishing-boats on those parts of the coast being an important consideration in determining what description or type of life-boat is most suitable to those localities, and in which the crews are likely to have confidence. In like manner, the improve-

ments that may be introduced in the fishing-boats, the opinions and even prejudices of those who risk their lives, and have practical experience, should have due consideration.

There not being time to go into the details of dimensions as shown in the first four columns, it will be useful to state shortly their relative properties under the following heads:—The proportion is shown by the ratio of the length and depth to the breadth in the 5th and 6th columns. The 7th column shows the external bulk in cubic feet to the height of the gunwale or deck. The 8th and 9th columns show the least draught of water, and the 10th column shows the area of the midship section, the principal elements of resistance combined with displacement. The 11th column is the angle of rise of floor, as shown in the Diagram of Sections. The 16th column records extra buoyancy, showing their capabilities as life-boats; and the cost, an important object in fishing-boats.

A view of this comparative analysis of the proportions of twelve life-boats and ten fishing-boats shows considerable difference in their proportions, form and fitting. Their size, bulk, or capacity for burthen, seem to have little reference to the cost. The Scotch fishing-boats (Buckie) of 1851 cubic feet bulk, cost only £60; while an English boat (Deal) of 1478 feet bulk, costs £275.

The lines of the Masula boat and Greathead's may be said to represent the type of the original life-boats in Asia and Europe—the Masula boat on the Madras coast being the oldest, cheapest, and probably the best. It is a flat, broad boat, built of light timber, sewed together in broad strakes, its only fittings being brushwood in the bottom; it goes through a very heavy surf on a steep beach. Greathead's represents the life-boats of the last century. The three next lines represent the special life-boats, elaborately fitted with valves and platform, including the Shields boat, Mr. Beeching's Prize Model, and Mr. Peake's first boat, altered at Woolwich in 1851–52.

The five next represent the light or ship's life-boats of Mr. George Palmer, M.P.; Costain of Liverpool; Francis of America; White of Cowes; and A. Henderson's ship's life-boat. The 11th line details the peculiarities of Beeching's Prize Model boats, which after several upsets, two drowning their crews at Lytham and Rhyl, have been removed from all the stations, or have had their fittings altered. That at Lytham is now replaced by one of the new boats built on Mr. Peake's principle.

The peculiarities of Mr. Beeching's Prize Model and the causes of failure are further explained by a diagram of midship sections and fittings appended to this Report.

The 13th line gives the dimensions of Peake's life-boats of 1856, with all the improvements in the fittings, obtained from the experience of some forty boats, built for the National Life-Boat Institution, and the necessary removal of Beeching's Prize Model fittings from all the life-boats under the control of the Committee of Naval Officers, who awarded the prize to the models in 1851. A detailed specification, section, body and sheer plan of these complete coast life-boats is appended to this Report.

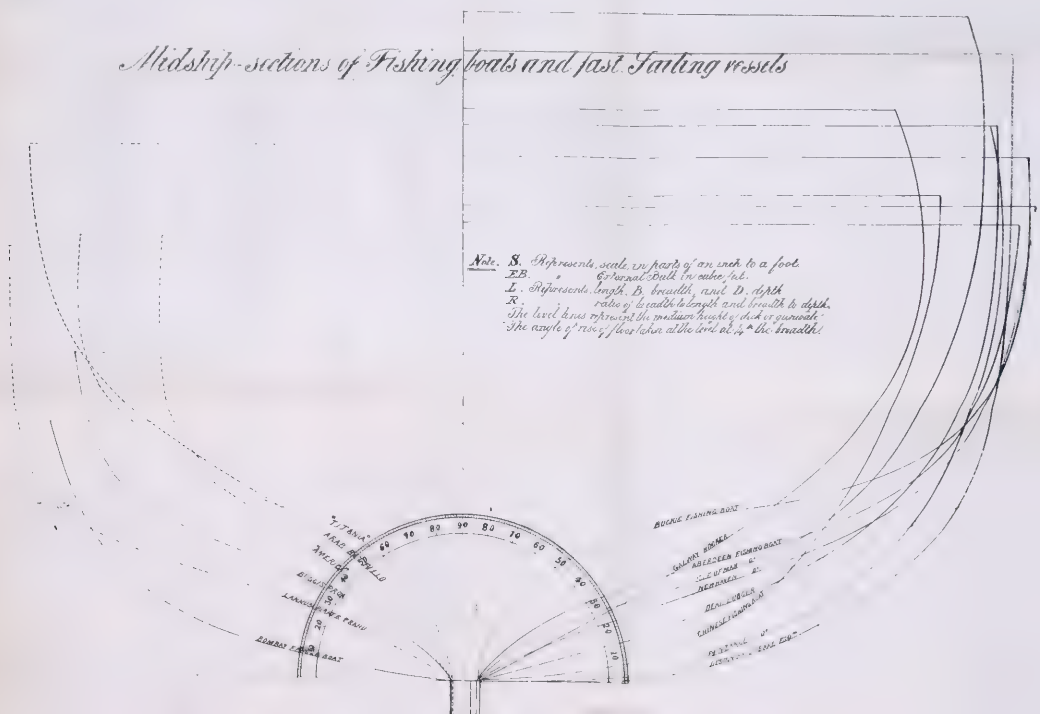
The 12th line gives the details of Henderson's Fishermen's life-boat, built at Liverpool in 1852, with experimental alterations made in 1853 and 1854, after trials on the coast by fishermen as to rig and fitting; the improvements being mainly the adaptation of the Chinese system of stretchers to the lug sails now used on our coasts, with moveable step to the mast, so extensively used by Chinese fishing-boats. There is also an iron drop-keel, as used in American boats. The proportions and forms of the boat are a modification of those of the Shetland fishing-boat and Yorkshire cobble.

TABULAR RETURN OF THE PARTICULARS OF LIFE-BOATS AND FISHING BOATS ON THE COASTS OF THE UNITED KINGDOM, 1856.

STATION, AND NAME OF DESIGNER OR BUILDER.	Year.	Length R. Rabbet E. External K. Length of Keel.	Breadth E. External L. Loading	Depth from Gunwale amidships to Rabbet in Keel.	Height of Gunwale at Stem and Stern above Rabbet in Keel.	Ratio of Length to Breadth.	Ratio of Depth to Breadth.	No. of Line.	Number of Men.	External Bulk to Medium Height of Gunwale or Deck.	Internal Space Height of Gunwale or Deck ÷ 100. N Tonnage	Displacement to Load Line, ⅔ Height Gunwale or Deck.	Mean Draft of Water.	Area of Midship Section.	Angle of rise of floor.	Number of Boats.	Cost of Boats.	Weight of Boat.	Ballast. W—Water T—Timber I—Iron C—Cork	Extra Buoyancy.	LIFE BOAT FITTINGS, BUILD, MATERIALS, AND ARRANGEMENTS FOR MANAGEMENT.	
								No.	No.	Cubic Feet.	Cubic Feet.	Tons. Cwt	F. I.	S Ft	Deg.	No.	£	Cwt.	Cwt.	Tons.		
Madras Coast, Masula Boat		24 0	8 9	4 6	5 6	2.7	.51	1		505		6 2			Flat						A Broad Flat Boat, built of light wood, sewed together in broad slopes	
Greathead's Life-boat		26 9	9 9	3 0	7 4	2.7	.37	2		405		6 0			8				None.		Original English Life Boat, broad shallow boat, rising floor, curved keel, and great sheer	
1st Class Boats: Shields Boat, that upset	1849	32 6	11 9	3 1	6 9	2.8	.26	3		626		9 4			6				W. 16	4	Special Life Boats of original type, having platform deck, with valves	
Beeching's Prize Model		34 6	9 3	3 6	7 0	3.7	.37	4		648		11 2			6		250	70	W. 50	8½		
[illegible] Peake's Woolwich	1851	29 0	8 6	3 6	4 8	3.4	.41	5		519		9 5			1		100	38	C. 5	3		
[illegible] Life-boat	1852																					
Light Ships Boat: George Palmer's	1828	25 0	6 6	3 3	6 0	3.8	.50	6		251		3 14			16		75	15	None.	2½	Light Ship's Life Boats, used and adapted to ships and coast with limited crew	
Liverpool, Costain's	1851	28 0	9 0	4 0	5 0	3.1	.44	7		512		7 14			17		180	37	None.	1		
America, Francis's	1851	25 0	6 9	2 6	5 3	3.6	.37	8		216		3 23			17		50	19	6	2		
White's (of Cowes) Boat	1851					3.8	.38	9							10		75	30	None.	2		
A. Henderson's Ship's Life-boat	1851	26 0	6 6	3 0	5 2	4.0	5.0	10		374		5 16			10		35	20	C. 1½	3		
B[illegible] Lytham, Rhyl, [illegible] other stations	1852	27 6	6 9	3 6		4.0	.51	11		349		5 19			5		125	35½	W. 20 I. 4	1	Beeching's Prize Model, large water ballast tanks, and self-righting power	
[illegible] man's Life-[illegible] 1852 altered [illegible]		28 0	7 0	3 2	1 7	1.0	5.0	12		441		7 4			1		100	39	C. 3 W. 10	1	Fisherman's Life Boat, fittings adapted to fishermen's boats or coast	
[illegible] Peake's Life-boat Institution	1853	30 0	7 6	3 8	5 5	4.0	.50	13		449		8 0			3		156	12	I. Keel & wood 13cwt.	1	Peake's Life Boat, of which some 50 have been built for National Life Boat Institution	
Fishing B[oats]: Shetland Fishing Boat		K25 0	7 4	2 7		3.8	.35	14		320		3 15			16		35	25	5.10		English and Scotch Fishing Boats, plans of which were published in Capt. Washington's Report on Scotch Fisheries, 1848	
Buckie Herring Boat		K30 0	12 9	4 9		2.9	.47	15		1851		16 0			17		[illegible]	[illegible]				
Fraserburgh open ditto		K32 0	13 0	5 0½		2.7	.41	16		1809		15 8			26		75	[illegible]				
Aberdeen ditto		K32 6	12 3	4 3		3.1		17		1277		24 16			31		65	88				
Newhaven ditto		K32 0	13 3	4 3		2.8		18		1123		21 16			22		85	86				
Deal Lugger		K35 6	12 0	5 0		3.09	.54	19		1487		20 8			14		275	65				
Penzance		K34 0	11 9	6 0		3.05	.61	20		1755		26 18			2		200	200				
Chinese Fishing Boat		42 10	10 2	4 2		3.8	.41	21		1341		18 14			7		60	60	Stone.		Indian and Chinese Fishing Boat	
Bombay, ditto, ditto		19 6	12 0	3 9		3.2	.31	22		1397		16 30			8		50	60	Do.			
Bay of Mersey: Liverpool Life Boat	1840	30 9	9 2	3 7	5 2			23	12	550			1.8			2	150	37	None.	1¼	Costain's plan, air casks and cork, diagonal	The Dock Trustees of Liverpool have maintained these efficient life-boats since 1840, assisting 338 vessels, and saving 1,456 lives, to 1854, at a cost of £2,000 a-year.
Hoylake	1841	30 0	9 2	3 7	5 2				12	550			1.8			2	129	37	None.	2¼	Costain's plan, only filling air casks and cork fenders, clenches, built of larch	
Magazines	1854	32 0	9 3	3 8	5 3				10	560			1.7			2	170	36	None.	2¼	Do. do. do. None of Liverpool life boats relieve themselves of water except by	
Point of Air	1844	24 0	8 6	3 6	5 1					520			1.5			1	120	32	None.	1½	Do. do. do. bucket, nor self-righting power. The Point of Air Boat recently	
Do. Do.	1845	30 0	9 3	3 8	5 2				12	550			1.8			1	129	37	None.	3	Do. do. do. upset, and drowned the crew. The boats are generally towed by	
Formby	1839	30 0	9 0	3 7	5 3					560			1.7			1	129	36		2	Do. do. do. a steamer	
Broadstairs, No. 1	1850	30 0	6 6	2 8												2			Shin. or W. W. and C.		Presented by Messrs. White, shipbuilders, of Cowes, for the use of the boatmen. (Light boat, of whale-boat form, diagonal, built of mahogany, air-compartiments between double sides from gunwale to keel; much used as Ship's Life-boat.)	
Broadstairs, No. 2	1852	30 0	8 4	3 0																		
Ramsgate	1851	36 0	9 6	4 11½												1	250	86			Beeching's Prize Boat, the fittings altered after Peake's plan, substituting iron keel for water ballast	Harbour Commissioners.
Dover	1853	28 0	7 6	3 2												1	150	27	I. 6 T. 3		Forrestt, after Peake	National Life Boat Institution.
Walmer	1856	30 0	7 6	3 8	5 5								1.8			1			I. 7½ T. 5½		Diagonal planking, two skins, water-tight deck above the load-line, self-righting air cases at bow and stem, and detached air cases alongsides (beneath the thwarts, 6 delivery tubes 6 inches in diameter	Do. Do.
Dungeness	1856	28 0	6 0	2 6									1.2			1	126	25			Diagonal Fir, as in all Mr. Peake's boats	Do. Do.
Rye	1853	27 0	7 6	3 1	5 4								1.8			1	135	40	I. 5 T. 5		Forrestt, after Peake, Clench Elm, do.	Do. Do.
Eastbourne	1822	25 0	8 6	3 10	1 4											1			Nil.		Simpson's Clench Oak, side and end air cases from floor to thwarts; no platform	Do. Do.
Newhaven	1852	29 0	7 3	3 5									1.10			1					Beeching's fittings, altered after Peake, for the Institution	Do. Do.
Brighton		22 6	6 6	2 10												1			Nil.			Town Commissioners.
Shoreham	1845	30 0	8 9	3 6												1	100		Water.		May and Twayts, of Shoreham, built after Liverpool boats, air casks under thwarts in wooden cases, three tubes with plugs	Harbour Commissioners.
Worthing	1853	27 0	7 6	3 5									.10			1			I. Keel 6		Harvey, after Peake, three delivery tubes without valves	Local Committee.
Lyme Regis	1853	27 0	7 6	3 2	5 5								1.5			1		40	I. 6 T. 3		Forrestt, after Peake, Clench Elm, as Mr. Peake's other boats	National Life Boat Institution.
Teignmouth	1852	28 0	7 0	3 2	5 7								1.8			1		40	I. 7 T. 3		Beeching's fittings, altered 1853 to Peake's, by Institution	Do. Do.
Penzance	1853	30 0	8 0	3 3	5 7								1.5			1					Forrestt, after Peake, Clench Elm, as Peake's other boats	Do. Do.
Sennit Cove	1853	25 0	6 8	2 10									1.7			1	125		I. 6 T. 4		Do. Do. Do.	Do. Do.
Padstow	1856	30 0	6 0	2 6	1 2								1.1			1			I. 4 T. 2		Do. Diagonal Fir Do.	Do. Do.
Budehaven	1853	27 0	7 6	3 2	5 5								1.8			1	135	40	I. 6 T. 3		Do. Clench Elm, as other boats of the Institution	Do. Do.
Appledore	1856	28 0	6 0	2 8									1.2			3	126	25			Peake's Diagonal Fir, as in Peake's other boats	Local Committee.
Bideford																2						Do.
Ilfracombe	1851	32 0	8 2													1					White, of Cowes, air cases built in round the sides; no delivery tubes	Bridgwater Trustees.
Burnham		26 4	9 11	3 3												1					Do. do. 6 delivery tubes	Harbour Trustees.
Swansea																						National Life Boat Institution.
Llanelly	1852	26 0	6 6	3 3												1	116		Water.		As in Beeching's boats with water ballast	Do. Do.
Tenby	1852	28 0	7 0	3 3	5 7								1.8			1		40	I. 7 T. 3		Beeching's fittings altered after Peake, as other boats of the Institution	Do. Do.
Fishguard	1855	30 0	7 6	3 5	5 0											1			I. 6 T. 5		Forrestt, after Peake, iron keel, timber ballast, and air cases under platform	Do. Do.
Cardigan	1849	27 0	8 0	2 9												1	116		Nil.		White, side air cases built in, as in White's boats	Harbour Trustees.
Aberystwith																					Taylor and Palmer, detached side air cases and end air cases, as in original boats of Institution, by Palmer	Do.
Aberdovey	1830	26 0	6 2	2 7	5 9											1	66		Nil.		Peake's cork in boxes under platform, 6 delivery valves, air cases in bow and stem and under thwarts, Clench built elm	Do.
Barmouth	1853	27 0	7 6	3 2	5 4								1.8			1			I. 6 C. 3			
Portmadoc	1854	28 0	7 8	3 2	5 3								1.8			1	140	40	I. 6 T. 4		Clench Elm, as in Mr. Peake's other boats	Do.
Carnarvon																1						Carnarvon Trust.
Llanwddyn	1840	27 0	6 3	2 9	4 0											1	65		Nil.		Palmer's original plan, air cases in bow, stem, and sides, clench built of elm	Anglesea Association and National Life Boat Institution.
Rhoscolyn	1848	26 0	6 6	2 6	3 8											1	60		Nil.		Do. Do. Do. Do.	
Holyhead	1828	32 0	8 4	2 8	3 8								1.			1	80		Nil.		McVea after Palmer Do. Do. Do.	
Cemlyn	1828	25 0	6 0	2 4									1.			1	55		Nil.		Harton after Palmer Do. Do. Do.	
Moelfre	1854	28 0	6 10	2 6	4 11								1.8			1	93	23½	Nil.		Griffith and Skinner, oak and larch, 4 delivery tubes, 3 inches in diameter	
Penmon	1848	27 0	7 0	2 7	3 8								1.4			1			Nil.		Costain and Griffith, air casks under thwarts, as Liverpool boats	
Rhyl	1856	32 0	8 4	4 8									.10			1	300	31	Nil.		Mr. Richardson's Tubular Life Boat, two iron cylinders, was navigated round coast to challenge trial, 1852. Built by Capt. Richardson for National Life Boat Institution, 1856, to replace Beeching's Prize Model, that upset, remained bottom up, and drowned 6 of the crew	
Liverpool		30 0	9 8	4 0						512		7 14		17		7	180	37	Nil.			
Whitehaven	1853	27 0	7 8	2 7½																	Forrestt, after Peake, by National Life Boat Institution, to replace Beeching's Prize Model. That, on trial, upset, remained bottom up, and drowned 8 of her crew	
Lytham	1855	30 0	7 6	3 4	4 10											1						
Scotland, Ayr to Dundee	1856	Boats. 13	Life	Boats.																	The particulars of these Life Boats are various as in the above records, being kept at Board of Trade yearly returns.	
England, Cullercoates to Harwich		48	Do.	Do.																		
Ireland, Drogheda to Kilnom		7	Do.	Do.																		

COMPARISON of MIDSHIP SECTIONS and WATER LINES of LIFE BOATS

Midship-sections of Fishing boats and fast Sailing vessels



The life-boat fittings are the result of practical experience in their adaptation to Francis's corrugated iron boats, and costly alterations in this boat for combining the buoyancy of timber with the strength of angle-iron frames. The life-boat fittings are so arranged as not to interfere with her usefulness as a fishing-boat, while, being only loose cork and casks, they can be placed in the boat while the life-boat's crew are collecting. A full description with section and sheer plan is appended to this Report; and a lithographic specification and building draft of this, as well as of the ship's life-boat, has been circulated amongst those interested in building and improving boats. There will be found on the back of the Tabular Return, a lithographic comparison of the midship section and water-lines of most of the life-boats enumerated, including the Tubular Life-boat, 'Challenger,' designed by Mr. Richardson, one of which is now stationed at Rhyl.

There are also the midship sections of the following fishing-boats—(the proportion, bulk, displacement and arc of midsection, are recorded in the Tables):—Buckie Herring boat; Tobermory open boat; Aberdeen and Newhaven open boats; the Deal lugger; Penzance or Cornish fishing lugger; the Chinese fishing-boat; and the Bombay fishing-boat.

The Tabular Return contains the builders and stations in 1856 of all the life-boats stationed on the coast, from the record of the Board of Trade and Royal National Life-Boat Institution.

It is to be hoped that by a continuation of these inquiries we may obtain the same information as to the fishing-boats on our coasts as we now have as to life-boats; for although it has occupied seven years to bring the life-boats to their present state of efficiency, it may be expected to take a much longer time to promote an improved construction of fishermen's boats, inasmuch as while the number of life-boats is under 300, that of fishing-boats exceeds 10,000.

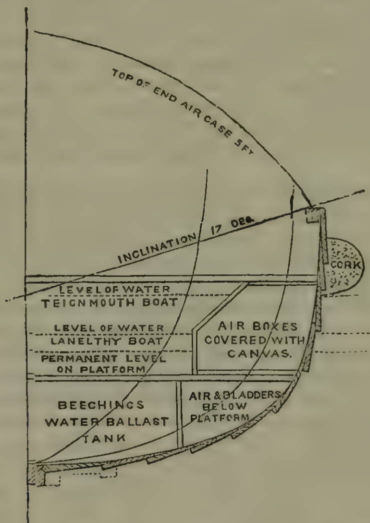
The initiation was taken in 1849, by the publication of Capt. Washington's Report and plans of fishing-boats, but no progress has been since made; the only public body in any way representing the fishermen on our coasts being the Fishing Board of Scotland, which has mainly directed its attention to the curing of fish and to the improvement of the harbours.

Moreover, the Fishing Board being subject to parliamentary inquiry, and uncertain as to its being maintained, may have prevented any efforts at improvement. A Commission which was appointed in 1856, and whose report was published in 1857, has confined its inquiries to the expediency of continuing the Board, and to the grants for harbours. We must look to private efforts and enterprise to effect any improvement in fishermen's boats, and follow the example set by the Duke of Northumberland, in offering a premium for the best fishermen's boat, and give effect to the competition by building experimental trial boats suited to the different localities, and making such alterations as practice proves necessary to meet the requirements of each fishing station.

This system has been carried out so admirably with life-boats, that I will briefly detail the progress of improvement, by describing the original Prize life-boat that was considered the best of 260 models submitted for competition to a committee of naval officers, who printed an able report, of which 1300 copies were circulated by the Duke of Northumberland. After costly alterations in the Northumberland life-boat at Woolwich, and many repeated alterations in form and fitting, and after constructing 40 boats, Mr. Peake of Woolwich Dockyard perfected the design which is illustrated by the accompanying Diagram and Plan, and shown in the model on the table and plans on the wall.

The peculiarities of Mr. Beeching's model and patent mode of fitting life-boats will be seen by reference to the annexed diagram of the midship section, from a drawing and specification of a 28-feet boat, which was tried at Woolwich dockyard in November 1851, in the presence of the Committee who awarded the prize. This boat, estimated at 22 cwt., weighed $29\frac{1}{2}$ cwt., and with oars, sails, and crew, 50 cwt. She had 19 cwt. of water ballast, and when upset under a crane righted herself readily. With crew on board, she drew 20 to 21 inches of water, the tubes admitting water 4 or 5 inches on top of platform. (See diagram.) This boat was sent to Teignmouth and tried 15th January, 1852, and when turned over under the crane laid bottom up three or four minutes, and with a crew of twelve men the water rose to within 2 inches of the thwarts. In December 1851, the Lytham boat, of the same dimensions, was tried at Liverpool, and when upset under the crane she righted herself; but on the suggestion of Mr. Beeching, some fourteen or sixteen men getting on one side, she upset, and remained bottom up three or four minutes, till assisted by the Liverpool life-boat men, most of whom expressed their opinion that she would prove dangerous.

Beeching's Prize Life-boat.



In 1852 the Shipwrecked Fishermen's Society sent the Prize-model boats to Tenby, Llanelly, Port Madoc, and Newhaven. The annexed midship section of one of these boats shows their form and fittings. The results of their trial being most important, I will here give a description of one of them. The platform, or air-tight deck, is one-third of the depth above the bottom. The principal feature is the water-ballast tank, extending over three-sevenths of the length and three-fifths of the breadth amidships. A 28-feet boat will contain upwards of a ton of water. The air space at the side and end is obtained by filled bladders, Eight 4-inch tubes pass through the ballast-tank and bottom, relieving the boat of water to the level of flotation.

Practically, all Beeching's boats retain the water at a level of 4 or 5 inches above the platform for three-fifths of the breadth, as shown on the diagram, and thus, when under sail, or laid over by a sea, this water, shifting to leeward, acts as a counter-ballast; and, as seen in the diagram, the Teignmouth boat, with an inclination of 17°, would have her lee gunwale immersed, and of some three tons of water above the platform four-fifths would be on the lee side; and should the compartments under the platform not be perfectly tight, the water ballast would also shift to the lee side, leaving air or vacuum on the weather side,—the alternate pressure of which and the water on the platform actually draws the oakum from the seams.

The *self-righting* power of Beeching's boats was obtained in the Prize-model by very large air-compartments in the bow and stern, occupying two-fifths of the length and as high as the stem above the gunwales, as shown in the midship section; these compartments containing 30 to 60 feet of air or buoyancy, forced the boat to right herself when turned over or upset; but experience proves that when often repeated, or in a sea way, its efficiency was neutralized by leakage, the increased weight of the boats rendering assistance necessary to right them. This is illustrated by the diagram, where the curved line shows the position of the end air-cases from stem to gunwale, which, when the boat is turned over, would be immersed to the level of the thwarts.

SPECIAL COAST LIFE-BOAT.

The Coast-Guard Life-boats include Hink's, Plenty, and Howden's model, the modification of the Admiralty boat, built also by Mr. Peake, and the many boats since built for the National Life-Boat Institution.

The result of Mr. Peake's experiments is shown by his last boat being four times as long as she is broad, with a flat floor and straight sides, but fine lines in bow and stern, with a considerable sheer of gunwale. The planking is of diagonal pine, and there is a water-tight platform or deck, one-third the depth, resting on four stout pine bulkheads athwart the boat, secured to the bottom to form air-tight compartments in bow and stern, the bilge spaces being filled with blocks of light pine, instead of cork or boxes as heretofore. In the midship part of the platform is a covered well, containing anchor, cable and stores, with air-boxes at the sides under the thwarts, and air-compartments in bow and stern up to height of gunwale. These assist in giving the power of "self-righting," and are aided by a thick cast-iron false keel, bolted to keel bottom and keelson, and weighing about 1 cwt. to every 3 feet of length. The boat frees itself of water by six tubes through the bottom fitted with self-acting relieving valves at the height of the platform. She is fitted to steer with oars, and to pull eight to twelve oars double-banked, to carry a small lug sail, and is provided with improved life-belts, waterproof coats and boots, and everything requisite for the special service of a life-boat at most of the stations on our coasts.

Thus it will be seen that the repeated experiments of Mr. Peake and myself have led to the adoption by both of a model very similar in its details, the only difference being, that whereas Mr. Peake's is intended for a coast life-boat only, useful for no other purposes, mine is for giving to a fisherman's boat the properties of a life-boat when requisite.

The annexed diagrams show the general form and the nature of the fittings and air-chambers of one of Mr. Peake's Life-boats, 30 ft. in length, and 7 ft. 6 in. in breadth.

In Figs. 1 and 2, corresponding to the elevation and deck plans, the general exterior form of the boat is seen, showing the sheer of gunwale, length of keel, and rake or slope of stem and stern-posts. The dark dotted

lines in Fig. 1 also show the position and dimensions of the air-chambers within-board and of the relieving tubes.

A represents the deck. B, the relieving tubes (6 in. diameter). C, the side air-cases. D, the end air-chambers.

In Fig. 3, the exterior form of transverse sections at different distances from stem to stern is shown. Fig. 4 represents a midship transverse section.

A represents sections of the side air-cases already described.

B, the relieving tubes, bored through solid massive chocks of wood, of the same depth as the space between the deck and the boat's floor.

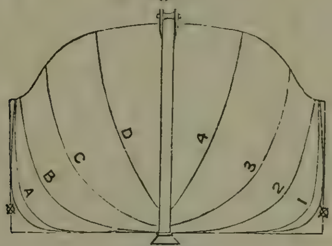
C, spaces beneath the deck, filled up over 6 ft. in length at the midship part of the boat with solid chocks of light wood, or boxes of cork, forming a portion of the ballast, as before described.

D, a section of a tier below the deck, having a moveable hatch or lid, in which the boat's cable is stowed, and into which all leakage beneath the deck is drained through small holes, with valves fixed in them. In some of the latter boats, a small draining tier only is placed, having a pump in it, by which any leakage can be pumped out by one of the crew whilst afloat.

The proportions of one of these boats are as follows:—

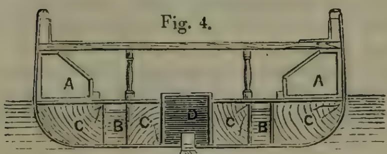
Length, 30 ft. Beam, 7 ft. 6 in. Depth amidships, 3 ft. 4 in., exclusive of keel. Depth from boat's floor to deck, 1 ft. 3 in. Depth from deck to thwarts, 1 ft. 3 in. Depth from thwarts to gunwale, 10 in. Length of end-cases (D), 4 ft. Width of side-cases (C), extreme, 1 ft. 6 in.

Fig. 3.



Body Plan.

Fig. 4.

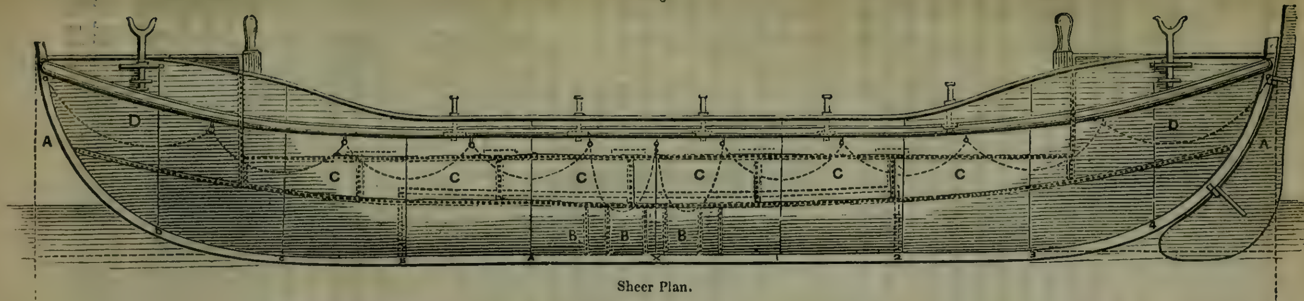


Midship Section.

The festooned lines in Fig. 1 represent exterior life-lines attached round the entire length of the boat, to which persons in the water might cling until they could be got into the boat: the two central life-lines are festooned lower than the others to be used as stirrups, so that a person in the water could more readily, by stepping on them, get into the boat, which is a very difficult operation for even a strong man to effect, with heavy, wet clothes about him.

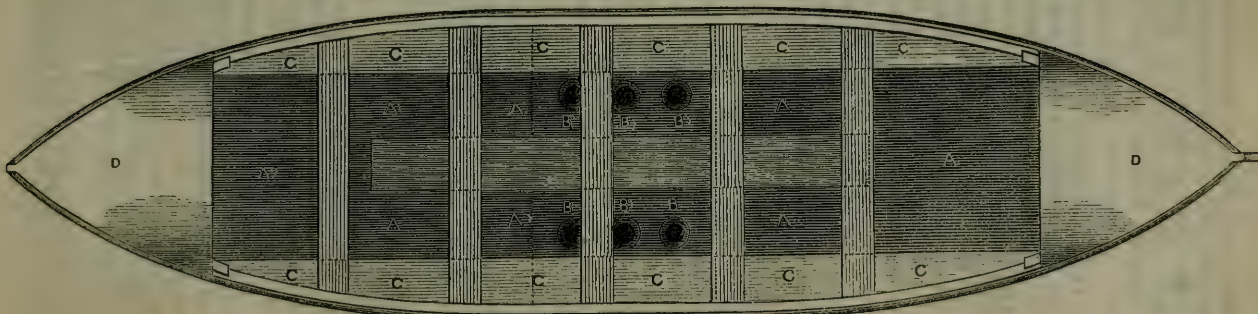
It may be observed, that several lighter boats have been lately constructed on Mr. Peake's design, of the dimensions and proportions of the Coast-guard

Fig. 1.



Sheer Plan.

Fig. 2.



galley; and there can be no doubt that if every coast-guard station were provided with boats built and fitted on this principle, a very great advantage would accrue, in the more safe and effective boats for the use of the coast-guard, while the number of efficient life-boats on the coasts of England, Ireland and Scotland would be at once doubled.

FISHERMEN'S LIFE-BOATS.

These are proposed to be formed by the addition of moveable corks and casks to the fittings of the various fishing-boats in use on different parts of the coast, the practicability of which is shown by the model of the boat built at Liverpool in 1852, which is a modification of the Life-boats of that port, of the Shetland Fishing-boat, and the Yorkshire Cobble.

In order to carry out this object, and to test the usefulness of the principles and alterations I advocated, I designed a boat in which the properties of a life-boat could be applied to the fishing-boats in use on our coast, without impairing their utility for the purposes of each locality, or much increasing their cost. In March 1852 the boat was building at Liverpool, and I took for her type the life-boats of that port, the fishing-boats of the Shetlands, and the North-country cobble, so as to obtain a light draft of water, and facilities in landing on a beach.

Her dimensions are—length, 28 feet; breadth, 7 feet; depth, 3 feet 6 in.; sheer of gunwale, 26 inches; external bulk to gunwale, 568 cubic feet; displacement when loaded to two-thirds of her depth, $7\frac{1}{4}$ tons. Clinch built of larch planks, on eight-angle-iron frames, having bulkheads athwart the boat to one-third of the depth. The annexed diagrams show this, and also exhibit the form and outside planking, angle-iron bilge, and false keel with iron drop or sliding-keel, and also the internal fittings of platform over bulkhead, wells, and tanks, the latter one-third the breadth and one-fourth the depth amidships. The diagrams also show the disposition of extra buoyancy of fishermen's cork life-buoys in bilge, and the position of the air-casks under the thwarts, with self-acting valves to relieve the water to the level of flotation, and pumps to discharge the water below.

The peculiarities of construction are the substitution for numerous small timbers of seven or more angle-iron frames, with bulkheads one-third the depth, which give strength, and divide the length into water-tight compartments, admitting fore-and-aft partitions. These divide the breadth of the boat into side-bilge and bottom compartments, the latter only being water-tight, with two water-ballast tanks of 29 cubic feet amidships, one-third the breadth at bottom and one-fourth at top, as shown in diagram. When empty they would have an extra buoyancy of 16 cwt. While full they would act as water-ballast, or be used as fish-wells by fishing-boats. Three smaller open wells collect the water, the centre one containing two relieving valves and two pumps, that clear both boat and ballast-tanks of water.

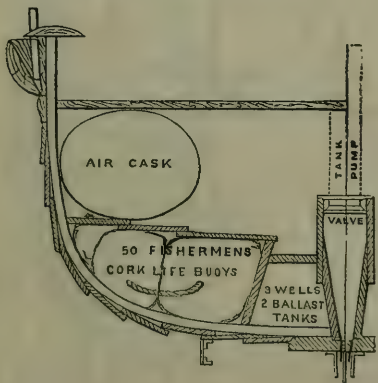
Self-righting power was attained by four air-casks, secured above the thwarts in bow and stern, weighing 50 lbs. each, and displacing 30 cubic feet or 17 cwt. of water, when the boat is turned over by the sea. The annexed sheer plan of stern of boat exhibits the disposition of air-casks and iron false keel above and below the water-line, which, when the boat is bottom up, displace half the weight of the boat before the gunwale is immersed, and counterbalanced by the ballast, cause the boat to right herself.

To test the combination of fishing- and life-boat fittings, the boat was placed at the disposal of four fishermen experienced in the estuary off the

Mersey and the Dee, and employed in trawling off Hoylake, in company with numerous fishing-boats, which were made shorter and of greater breadth, drawing 2 to 3 feet more water, and having three to five tons of stone ballast. On trial, the "Life-boat" held good way with the fishing-boats while dragging the trawl, but when beating to windward, the deep-keel fishing-boats were more weatherly; and the fishermen stated that the life-boat was too buoyant or floaty, and that there was difficulty in keeping the fish-wells water-tight.

To obviate these objections, the bulkheads and partitions of wells were secured to bottom, the angle-iron false keel and drop keel being substituted for the flat false keel, increasing the weight 3 cwt. These have been found to answer the purpose intended, the boat retaining her self-righting power, while at the same time the sliding keel makes her more weatherly and stiff when down, and admits of the boat being sailed into shoal water. She was allowed to take the ground on a rocky bottom without injury in a close reef breeze.

Henderson's Fishermen's Life-boat, built at Liverpool.—Midship section. Scale, ½ inch to a foot.

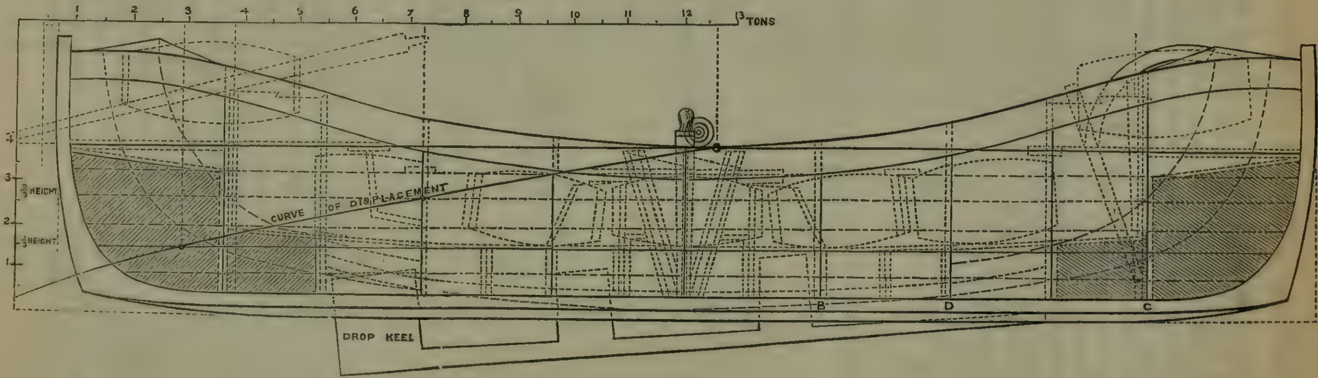


The advantage of the sliding keel, both to fishing- and life-boats, was exemplified last year by the unfortunate loss of one of the crew of the Liverpool Life-boat, near Formby, who had gone out fishing in one of the small, but deep draft fishing-boats with his son, and was obliged to attempt to land on a sandbank, the boat drawing so much water when she took the ground, that the sea turned her over and drowned him. *With the sliding keel up*, the "Fishermen's Life-boat" would have taken the ground in about two feet of water, where the sea would hardly have depth to turn the boat over, or prevent the crew landing. *With the sliding keel down*, the "Fishermen's Life-boat" would have crossed Rhyl bar, under sail, without upsetting, as Beeching's Prize Life-boat did, on the 22nd of January, 1853, by rolling over to windward and remaining bottom up till six of the crew were drowned.

From investigation on the spot, and from the survivors, the upsetting is clearly traceable to the weight of water above the platform, and water-ballast

Henderson's Fishermen's Life-boat.

Built 1853, to combine the form and properties of the Scotch Fishing Boat and the Yorkshire Cobble with the rig and fittings of Chinese Boats and the drop keel of American Boats.



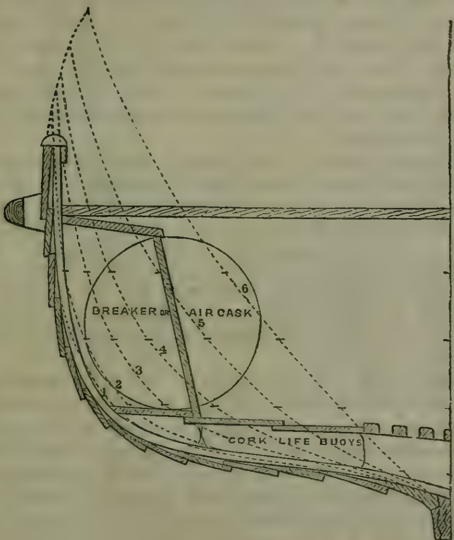
Sheer plan showing Life-boat fittings applied to Fishermen's boats. Scale, $\frac{1}{4}$ inch to a foot.

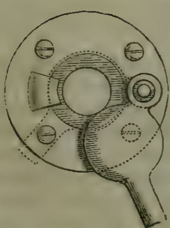
below moving to windward with the roll. This destroyed the stability and overcame the buoyancy, as it had before done in so many trials of Beeching's boats. The principle of the latter is now condemned by the alteration of nearly all the boats he has built for the Duke of Northumberland, Ramsgate, and the "Shipwrecked Fishermen's Society," who ordered this boat for the Rhyl station in preference to accepting my offer to place at their disposal my Fishermen's Life-boat.

SHIPS' LIFE-BOAT.

The magnitude of our mercantile marine, the great increase in the size of our ships, the number of steamers, and our numerous sea-going population, make the exhibition of an improved construction of "ships' life-boat" a great desideratum. Following in the steps of my respected friend, the late George

Henderson's Ships' Life-boat.—Scale, $\frac{5}{8}$ths of an inch.





Palmer, Esq., I have designed a plan and specification of a ship's life-boat, with a view to apply the properties of a life-boat to the ships' boats in ordi-

nary use at sea. Bearing in mind the necessity of their being light and strong, and the fittings such as can be easily repaired or renewed without increasing the cost of the usual boats, I have designed her to be built of light pine, clench built, on eight angle-iron frames, riveted to an angle-iron keel on stem and stern plate, also to an angle-iron stringer under the thwarts, and an angle-iron gunwale piece. Bulkheads of pine are riveted athwart the frames, one-fourth the depth from keel and one-eighth the breadth under the thwarts. The disposition of planking and internal fittings are shown in the annexed diagram of the main breadth section of a medium-sized boat, 28 feet long, 7 feet broad, and 3 feet 6 inches deep, having 10° rise of floor, with the little hollow near the keel; the sheer of gunwale an inch to a foot; the water-lines hollow forward, one straight aft; eight thwarts, 3 feet 6 inches apart.

The buoyancy is comprised in side compartments, between a rising plank fore-and-aft under the thwarts (between the bulkheads, $\frac{1}{8}$th of the breadth broad), and a fore-and-aft platform over the bulkhead at the bilge; the bow and stern partitions to be made up by a side plank, as shown on the section; between midship thwarts to be filled by six air-casks or water-breakers; the bilge below the platform to be filled with cork: the plan will show the position of the air compartments in bow and stern. The weight of this boat is calculated at one ton, and it will displace about five tons, and when filled to the level of thwarts with water will have buoyancy sufficient to carry thirty men.

The small diagram shows a zinc plug, of simple construction, intended to be screwed to the bottom plank, where the usual cork or wooden plug is placed; but as the former gets lost, and the latter often splits the plank, the zinc plug, which closes by turning a flat ridge over the faced collar or hole, secured by screw, and costs only 1*s.* 6*d.*, is preferable. I am assured that the boats can be built for 18*s.* to 24*s.* a foot, by the boat-builders usually employed in building ships' boats, on a plan and specification which have been lithographed and distributed, in the hope of inducing shipowners to make trial of such a combination of wood and iron as will give the greatest strength with the least weight.

Lowering Ship's Boat.—With respect to this very important question, after much experience I am convinced that the mode adopted by whalers is the simplest and best. That mode consists in strong davits, a good purchase of two large threefold blocks, with swivel hooks, into a shackle at the top of the stem- and stern-post. The boat to hang, as will be seen in the annexed diagram of a ship's side, with the usual iron davits and quarter-boats.

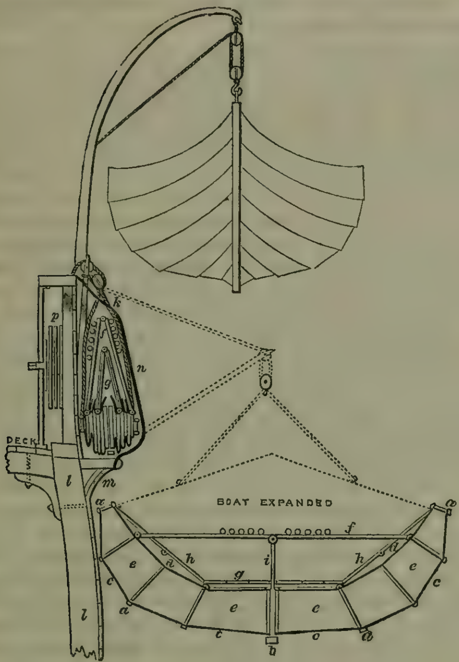
Our large steamers, transports, and emigrant ships, might carry a sufficient number of these boats at davits, with the addition of a collapsing life-boat stowed outside the bulwark, with separate davits, as shown in the diagram annexed, to enable them to be provided with the means of saving all on board in case of wreck or fire.

The Rev. J. S. Berthon, of Fareham, having for years devoted much time, labour, and money to the perfection of his invention, the following brief description is offered in explanation of the diagram of his collapsing life-boat, for providing abundant boat accommodation to all sea-going ships:—

The framework, which is made of wood, with bands and fastenings of metal, is composed of longitudinal timbers running the whole length, and hinged at their ends to each other, and to the top of the stem- and stern-post, as in expanded boats. They are broad and deep, and extend two skins of a very strong flexible waterproof material, the outer skin being firmly attached to their outer edges, *c*, and the inner one to their inner edges. The whole body of the boat is thus divided into as many water-tight longitudinal

compartments as there are spaces (usually eight) between the timbers. These air-cells fill themselves with air in the act of expansion, *e*. The

Conveying Ships' Life-boats at Davits.



Berthon's Collapsing Boat.

mode of hanging is shown in the annexed diagram of life-boat; *p* and *k* representing the lowering machine inside, and the boat in a collapsed state outside the bulwark of the ship, admitting of another boat being carried at the usual davits.

The extension of this boat, which is instantaneous when its weight is allowed to fall upon certain slings or spans attached to its gunwales, requires no exertion of manual strength, and it is kept permanently open by the thwarts, bottom boards, and certain gunwale stanchions.

The space required to stow these boats (viz. outside the ship's bulwarks with strong strappings) is about one-sixth of their width when open, so that numerous boats can thus be carried in constant readiness, and when in action they are inferior to none in buoyancy, safety, general efficiency as life-boats, and speed under sail or oars. The cost is about the same as that of the best ships' life-boats.

These boats have been most favourably reported on by the officers of Her Majesty's Dockyard at Portsmouth, by order of the Admiralty, and some large pinnaces on this principle, now built for the Government, will be shortly under trial in the Royal Navy.

STANDARD FOR SHIPS' LIFE-BOATS.

The necessity of establishing a Standard for Ships' Life-Boats, and the organization of a Committee to investigate the question as to Improved Means of Lowering Ships' Boats, and providing Life-preserving Apparatus on board British Ships.

The first efforts to establish ships' life-boats were made by the late George Palmer, Esq., M.P. for Essex, in 1828, when in command of East India Company's ships, on board which, and by the National Life-Boat Institution, they were adopted. Mr. Palmer circulated a sketch and specification of his boat and fittings, the extra buoyancy consisting of air-cases and casks in the wings, bow and stern, and under the thwarts. She was built as a whale-boat, sharp at both ends, so as to be carried at davits with convenience.

The second effort, in 1850, was the adoption of corrugated metal boats, patented by Mr. Francis of New York. These are largely employed by Government on the coast of America; and by an Act of Congress, passenger-ships are compelled to carry a certain number of these boats.

Machinery is now being erected at Liverpool for the formation of these iron boats by hydraulic pressure, as well as of a ship's quarter-boat (Pl. V.), and as these corrugated iron boats remain uninjured by the weather or the heat of the boiler, they are largely used by steamers and passenger ships.

Of the 280 models competing for the Northumberland prize in 1851, Messrs. White's, of Cowes, models have proved admirable ships' life-boats, with air-compartments between bilge and gunwale. Many are in use by the steam companies, but, from their high cost, do not come into general use—the air-compartments occupying most of the space, and being difficult to repair.

The principal life-boats now carried by steamers, passenger- and emigrant-ships are generally far inferior to the above, their extra buoyancy being merely copper or zinc cylinders placed under the thwarts; these are again boxed in by planks. Even with this protection it appears, from much experience, that the copper cannot be depended on for more than one year; and no dependence at all can be placed on the zinc tube or cylinder. These air-cases or tubes are in most life-boats placed so high in the boat as to be of little effect—in fact they are only *life-boats in name, and not in reality.*

The origin of this evil is to be found in one of the many inconsistencies in the Merchant Shipping Act of 1854, some of the 580 clauses of which enact that any ship carrying more than ten passengers shall be provided with life-boats and life-belts, but in no way define the fittings and characteristics of the life-boats to be carried.

The limit to passenger-ships excludes more than half the 36,000 British vessels, and there is no provision for the crews of the thousands of ships with fewer than ten passengers.

What is more extraordinary still, there is no officially-recognized standard according to which the life-boat should be constructed. The Emigration Office has some discretionary power, but practically it has come to a mere question of whether the zinc tubes should be 10 or 6 inches in diameter, and with the owners it is a code of £ *s. d.* In the majority of cases, when a ship is taken up by Government, or a life-boat is required under the Passengers' Act, experience has shown the usage to be for the owner or agent to look for the smallest and cheapest fitted boat that will be passed as a life-boat under the Act, or to the fitting of the ship's boats with the appearance of a life-boat by placing a light pine bulkhead on each side from the bilge to the thwart, with a covering at that height between them. In the best of

these boats the space between this planking is filled with copper or zinc cases; but in many of them it is only partially filled with zinc tubing 10 to 6 inches diameter, and in some only with cork shavings, so as to be wholly inefficient when new, and liable to be injured and become sodden and lose all buoyancy in a year.

By inquiries of those interested in shipping, any one may satisfy himself that this is the present position of the legal part of the question; and a walk round the harbours, quays, or docks, and inspection of some of the vessels, will lead to the following conclusions as to the present practice on board merchant-ships:—

That the provision of life-boats at all is quite an exception; that the principal ships in the passenger and American trade have ceased to carry large long-boats and yawls on their decks, but have substituted deck-houses and two light boats on the top, and often two more on beams over the quarter-deck, bottom up.

That sailing-ships have usually one pair of iron boat's davits on each side, some having two pairs; while steamers and screw vessels have three, and some of the larger four pairs of davits each side; this innovation being necessary from the increased length and depth of modern vessels, while the numerous passengers or emigrants now carried by each render it more imperative that proper provision be made for the preservation of the lives of all on board, in case of accident to ship or machinery.

It is curious to observe in the ships in the docks, that while great improvement has taken place in the mechanical arrangements connected with the sails and engines, no attention seems to be paid to the application of experience or science where the safety of life is to be secured, by the suitable construction of boats' davits and fittings, and the application of buoyancy to life-boats.

It will be seen that in nearly all the ships and steamers, the boats' davits are only a thick bar of round iron, with the head bent at right angles 3 or 4 feet, having a double or threefold block bolted to the end; with a tackle-block having an iron stop and hook, the boat being attached to the tackle by a chain sling, into which the tackle-block hooks; the difficulty being, that before the boat can be cleared of the tackle in a sea-way or under way, the rope must be so slack that the upper part of the block must be brought to the level of the sling and hook.

Although, with an experienced crew, these arrangements may have been found sufficient for the ordinary purposes of a merchant-ship, there can be no doubt there is great room for improvement in the detail of fitting; while the increase of passengers and loss of life by sudden accidents and collisions render it essential that every boat should be provided with the best mechanical means of being lowered in safety when full of the people she is intended to save.

This necessity has brought forward a number of proposed plans and patents for effecting the object; having my own views, I will quote those of an anonymous writer in the 'Shipwrecked Mariner,' on those of Messrs. Jeffreys, Lacon, Russell, Clifford, and Cornish, each having its respective merits. The objects sought were—1. That both ends should be lowered so as to secure the descent perfectly horizontal. 2. That they should not cant in the act of lowering. 3. That there should be power to disengage them as soon as they reach the water. 4. That there should be facilities for replacing the boats at their davits after being lowered at sea.

The first two objects were attained by Jeffreys, Lacon, Russell, and Clifford's plans, but I do not consider them so important as the last two objects. On these points, as well as the others, the writer in the 'Shipwrecked Ma-

riner' gives the plans of Mr. Jeffreys and Mr. Russell the most decided preference over those of Messrs. Lacon, Cornish, and Clifford; they all required some heavy and costly machinery for each pair of davits; Mr. Clifford's having the peculiarity, that his machinery is affixed under the midship thwart of the boat, for the sole purpose of allowing one man to lower both ends by two single ropes through threefold friction-blocks or nipping-sheaves, which preclude the possibility of hoisting them up by the same means that lower them.

Attempts having been made in Parliament to force Clifford's patent on the shipowners of the country, all really interested should cooperate in the establishment of a Ship's Life-boat and Fittings Committee, to elicit the views and opinions of those whose position or nautical experience enables them to afford information and suggestions as to the requirements of shipping, and the means of improving the boats and davits now in use, also of providing efficient life-preserving apparatus in all ships, without compulsory acts of parliament in favour of any patent.

The only vessels in which Government dictation would be just, are crowded troop-ships and emigrant-ships, to which extra life-boats, davits, and apparatus should be provided while so employed; and the only patent which would meet these requirements is the admirable invention of the Rev. E. J. Berthon, of an efficient collapsing life-boat, provided with patent davits and lowering apparatus, which can be carried in addition to the usual boats and davits, as shown in the annexed diagram and section (p. 325).

As to a *standard for ships' life-boats*, there are several different types which experience has established as efficient, such as Francis's corrugated iron boats, adopted by the American Government steamers; also those of White of Cowes, so largely employed by the mail steamers from Southampton; and, it may be, there are others with sufficient extra buoyancy to float with their complement of crew and passengers when filled by a sea, which may be estimated at 20 cubic feet of air or cork. Considering this as the minimum, the exact amount depends so much on the material and disposition of buoyancy, that it can only be determined by careful experiments and calculations, corroborated by records of their performances at sea. This requires the cooperation of many commanders of vessels, who only need that the points of inquiry be properly put before them, as has been done in the case of the Compass Committee of Liverpool.

For eliciting this information, the writer has lithographed a plan and specification of a ship's life-boat of 28 feet, with calculations of weight less than one ton, the hull and fittings having a buoyancy of about 15 hundredweight, and an extra buoyancy in the air-compartments and casks exceeding 50 cubic feet or $1\frac{1}{4}$ ton, sufficient to float the boat and upwards of 30 men. The only difference from the present boats is the substitution, for the present timber, of angle-iron frames to which pine bulkheads are riveted, so as to form air-compartments in bow and stern, the sides amidships being filled with 4 to 6 air-casks, and on the bilge and bottom 24 pairs of cork life-buoys, in place of the zinc tubes and cork-shavings now in use. It has been intimated that these boats could be built and fitted for 18*s.* to 20*s.* per foot.

As the principal impediment to the improvement of ships' life-boats and fittings is *the increased expense to the shipowner*, and the difficulty in obtaining boats and davits efficient and ready when required, it is to be hoped that some shipbuilders may be induced to build and forge a few such standard life-boats and davits as may be recommended by the Committee, or that subscriptions may be raised for the first or experimental boats. 500 copies of this plan and specification have been gratuitously circulated.

Boats' Davits.—As to *boats' davits and tackle-blocks*, having experienced loss of boats from the bending of iron davits, and the difficulty of hoisting boats up in sea-way, in 1835, the writer was induced to alter the curve and form of the iron davits, and to adopt large threefold blocks with swivel hooks, which resulted in greater security to the boats and much facility in lowering and recovering them at sea; and with reference to the before-mentioned right-angle and round form of davits, and small blocks now in use, the expediency of exhibiting an improved construction of both is suggested.

As to davits, it is proposed to increase the strength with reduced weight, by giving a less acute angle to the curve, and, by increasing the width of the davit in the direction of the curve, to double the diameter of the round part at the clamp or rail. Or from the rail upwards the davit may be converted from double-headed railway-bars, the thick parts of railway-bar, forming the top and bottom of the davit along the curve, to be welded together at the upper end, to hang the tackle block,—also to carry a roller, over which a single pennant will run, so as to lower the boat by single ropes from the ship when under way, the end of the rope running through one roller freeing the boat from the ship. This is a modification of Guthrie's plan already adopted in the Peninsular and Oriental Company's steamers, being lowered by two men on board the ship, and in opposition to Mr. Clifford's plan of one man in the centre of the boat lowering her by two ropes through four sheaves, one in the bottom of the boat.

As to blocks, it is proposed to use large threefold wooden blocks with iron inside straps, the upper block to have a swivel-hook, the lower block to have a hook hung on a pin connecting the inside straps of the block, so that the hook can be disengaged from the sling without turning the block.

Mr. Ewing, of Birkenhead, has made a model of this block, which is exhibited, and may be inspected at the Mercantile Marine Association Rooms, 20 Water Street, Liverpool, where any suggestions for the furtherance of the formation of a Ship's Life-boat and Fittings Committee will be thankfully received.

There are also models and plans of boats' davits, slings, valves, and life-boat fittings, submitted for the consideration of the Members of the Association.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Mathematics.

Opening Address by the Rev. T. R. Robinson, *D.D., F.R.S., M.R.I.A., President of the Section.*

In opening the proceedings of this Section of the Association, I hope a few minutes of your time, precious though it be, will not be misemployed in pointing out to those of you who have not specially devoted yourselves to its pursuits their paramount importance. Its highest department, mathematical science, is the noblest, the most nearly approaching to what we may suppose to be the kind of knowledge possessed by beings of an order superior to our own, which man can attain. By it alone we reach that which is the great aim of the good and wise, absolute truth. All the rest of our knowledge is only probable, varying in degree from the verge of certainty down to mere shadowy conjecture, and trustworthy exactly in proportion as the intellectual processes which deduce it are trained and used in analogy to its practice. It is also our mightiest aid in exploring the wide fields of physical and mechanical science: in the first, without its guiding light, we wander in a region of phantoms; in the other, though empirical, or, as it is often called, practical knowledge, may give an uncertain gleam, yet they who trust to it alone will find ruin and failure in their path. Yet with all its supreme dominion, it can only be attractive to a very few, and the inferior objects of our Section—as Optics, Electricity, Magnetism, Meteorology, and the like—will always be more popular. It were an evil hour for the human race in which it should sink into a secondary place: we have always upheld it, as I trust we always shall do, as our guiding banner. But even for the others we have not laboured in vain, as was so well shown last night by our accomplished President. His words carried me back to the time when, twenty-two years ago, we met in this city for the first time; and reminded me of the important researches which were originated at that meeting, and of the success with which they were carried out. Some of them I shall name as evidence of what the British Association has done for science. To begin with my own special pursuits.—1. There had been made at Greenwich during the preceding century a vast series of solar, lunar, and planetary observations, matchless in the world, of the highest importance to perfect the planetary theory, but quite useless, because unreduced. How troublesome that work is, none know but they who have used it; and it would, perhaps, never have been performed but that we obtained it from Government. It has been perfectly accomplished under the direction of Mr. Airy. —2. There existed a collection of star observations, the 'Histoire Céleste,' the proudest distinction of the two Lalandes, comprising 50,000 stars, all, however, unreduced and nearly useless. These we have reduced; and at a large pecuniary outlay, we have given to astronomers a catalogue not of less value than those of Bradley or Piazzi.—3. We originated those researches on the strength of iron, by which Hodgkinson and Fair-

bairn have added so much to the resources of constructive engineers.—4. We called for the investigations, and supplied funds for those discussions of tidal phenomena by which Dr. Whewell has not only thrown light on a most difficult portion of hydrodynamics, but given precious aid to the practical navigator.—5. Two years before that meeting, a great physicist had declared that to improve by theory the form of ships was as hopeless as to get the equation of a breaker; at that meeting a young man, then unknown, produced the germ of those researches, which, extended under our auspices, and largely aided by our pecuniary grants, have given J. Scott Russell a world-wide fame, and made possible the construction of those noble ships which, during the last month, have borne from your bay, at a speed twice what was once thought attainable, their freight of heroes, to uphold our nation's power, to avenge our slaughtered countrymen.—6. Lastly, we set on foot that system of magnetic observation of which you heard last night, which has added so much to our knowledge of terrestrial magnetism; nay, which has gone beyond our globe and opened a new range for inquiry, by showing us that this wondrous agent has power in other parts of the solar system. Is not this a list of achievements on which those of us who were then present may look with just pride? May we not venture to hope that when, in the next of its cycles, the Association shall return to this city, those who may survive to witness that event shall have it in their power to record one yet more brilliant? I cannot expect to be of the number, but the recollection that I have, however slightly, been a partaker in those labours in which the Association has worked so well to increase the knowledge and happiness of mankind, and the anticipation that it will continue to advance in the paths of the purest and highest wisdom, will cheer the remnant of my appointed time. For that advance we must prepare the way, and an occasion seems to offer now. The combined series of magnetic observations to which I have referred has just closed; and I cannot doubt that it is our duty to seek for its continuance and extension on a scale commensurate to the enlarged views which it has already opened. I shall therefore soon seek to obtain your concurrence in a recommendation to this effect, and am confident that we shall open a path to a series of new discoveries as much surpassing those which we have commemorated, as our present experience of the mode of making these researches transcends the imperfect methods with which they were commenced. I shall detain you no longer from your work. To mark our sense of the incalculable importance of pure mathematics, we always endeavour to devote to it the first days of our week. I cannot, therefore, promise anything attractive, or even intelligible to all of you; but Monday will be given to Meteorology, and Tuesday to Optics, Electricity and Magnetism, which I hope may prove of more general interest.

On the Theory of Astronomical Observations, and on some related Questions. By Professor BOOLE, *F.R.S.*

The author gave a short *résumé* of Gauss's theory of the value of astronomical and other observations, and the method of least squares. He then showed that the common mode of taking means depended on a theorem, which was only one case of a much more general theorem in probabilities which he had arrived at, and which he explained in full to the Section, with the formulæ, which he wrote on the board. He showed that it is only where each of the observations is equally trustworthy that our common mode of taking means can lead to correct results; and then showed that the same theorem furnished the principle for estimating the dependence to be placed on testimony and other kindred questions.

On certain Additions to the Integral Calculus. By Professor BOOLE, *F.R.S.*

On a System of Geodetics and the Conjugate System, traced on the two Sheets of a Surface of Centres, with special reference to the Case in which the Surface of Centres consists of an Ellipsoid and a Confocal Hyperboloid. By Professor CURTIS.

On the Interpretation of certain Symbolic Formulæ and Extensions of Taylor's *Theorem. By the* Rev. CHARLES GRAVES, *D.D., M.R.I.A.*

On some Application of Quaternions to Cones of the Third Degree. By Sir W. R. HAMILTON, *LL.D., M.R.I.A.*

On the Icosian Calculus. By Sir W. R. HAMILTON, *LL.D., M.R.I.A.*

The author stated that this calculus was entirely distinct from that of quaternions, and in it none of the roots concerned were imaginary. He then explained the leading features of the new calculus, and exemplified its use by an amusing game, which he called the Icosian, and which he had been led to invent by it,—a lithograph of which he distributed through the Section, and examples of what the game proposed to be accomplished were lithographed in the margin, the solutions being shown to be exemplifications of the calculus. The figure was the projection on a plane of the regular pentagonal dodecahedron, and at each of the angles were holes for receiving the ivory pins with which the game was played.

On Infinite Angles and on the Principle of Mean Values. By Mr. Commissioner HARGRAVE.

On the Origin and Elimination of Euclid's "*Reductio ad absurdum.*" *By* JOHN POPE HENNESSY, *of the Inner Temple.*

The author first pointed out the difference between direct and indirect demonstration. The enunciation of every geometrical theorem is a conclusion. This conclusion may be proved in either of two ways: (1) either by the simple syllogistic method, or (2) by a combination of that method with the principle of opposition. Mr. Hennessy showed that every proposition which Euclid proves directly belongs to the first, and that every proposition proved indirectly belongs to the second class. The origin of the *Reductio ad absurdum* was thus resolved into the question, why the principle of logical opposition should be employed in some cases and not in others. He showed that the necessity for calling in the aid of logical opposition depended on two abnormal conditions: (1) when any of the premises of an affirmative proposition are negative, and (2) when none of the premises of a negative proposition are negative. He then adverted to the number of indirect demonstrations which Euclid had left in the first six books of the 'Elements,' and to the very small number of these which succeeding geometers had altered. He concluded by submitting direct proofs of every proposition hitherto proved indirectly.

On some General Propositions connected with the Theory of Attractions. By the Rev. Professor JELLETT, *M.A., M.R.I.A.*

The author showed that the attraction of a body whose particles act with a force varying inversely as *any* odd power of the distances, may be easily deduced from that of a body having the same form and quantity of matter, the law of attraction being the inverse *first* power of the distance. He showed further, that while a knowledge of the attraction of a body whose particles act according to the law of nature, that is to say, the inverse square of the distance, gives us no information as to any other law (at least in this method), the knowledge of the attraction for the inverse fourth power gives it for every higher inverse power.

From these theorems he proved that there is no law of force capable of being represented by a series of inverse powers of the distance, except the law of nature, for which a body will attract as if its mass were concentrated at a fixed point.

He showed also that there is no law of force capable of being represented by a finite series of inverse powers of the distance, except the law of nature, for which a shell of any form will exercise no attraction on a point within it. If then the

particles of the electrical fluid acted on each other according to any such law, except that of nature, free electricity, instead of residing as it does entirely on the surface, would be dispersed through the entire of the changed body.

These theorems have been hitherto (so far as the author is aware) known only for a spherical surface.

After alluding to a well-known theorem of Chasles, he stated as a generalization, that if any two bodies have one external *equilibrium* surface common, then attraction at any point of external space will be in the same direction, and proportional to the masses of the bodies, the law of force being that of nature.

On certain Properties of the Radii of Curvature of Curves and Surfaces, and their Application to the Method of Polar Reciprocation. By T. Martin, *A.B., T.C.D.*

The author drew the attention of the Association to certain equations connecting the principal radii of curvature of a surface and its polar reciprocal at corresponding points, and of their inverse surfaces, and deduced the analogous equations for curves.

He then pointed out the peculiar power of these equations in transforming theorems of quantity, which he illustrated by selecting some of the most familiar properties of curves and surfaces of the second order, thereby with facility and despatch arriving at some novel and elegant conclusions.

A Demonstration that the Three Angles of every Triangle are equal to Two Right Angles. By B. A. Murray.

On the Surface of Centres of an Ellipsoid. By the Rev. G. Salmon, *D.D., M.R.I.A.*

Light, Optical Instruments.

On the Centring of the Lenses of the Compound Object-Glasses of Microscopes. By Sir David Brewster, *K.H., LL.D., F.R.S. L. & E.*

The author said,—In studying the subject of diffraction, as observed through the microscope, I was led to believe that in the best object-glasses now made the axes of the individual lenses are not coincident. I have no means of learning by what process the optician centres his lenses and groups of lenses, but it must be a very delicate one, when we consider the small size of the lenses, and the great depth of their curves; and I have no doubt that, however imperfect, it is one which is anxiously and carefully applied. You are, no doubt, acquainted with Dr. Wollaston's interesting paper, "On the Concentric Adjustment of a Triple Object-Glass" (Phil. Trans., 1822, p. 32), 45 inches in focal length, executed by the celebrated John Dollond, and regarded as one of his best works. By a process which he has described, Dr. Wollaston found that it was very imperfectly centred; and, contrary to the advice of his friends he separated the lenses, and by applying two pairs of adjusting screws to the edges of each lens, he placed their axes in the same line, and to use his own words, "he restored his object-glass to such correct performance," that it was "capable of either separating very small and nearly equal stars, as those of 44 Bootis and σ Coronæ, or of exhibiting the minute secondaries of β Orionis and 24 Aquilæ, with as much distinctness as the state of the air would admit." Dr. Wollaston adds, "that the actual limit to its powers cannot be fully ascertained, excepting under such favourable conditions of the atmosphere as do but rarely occur." If such a distinguished artist as Dollond failed in centring a group of three lenses, about 4 inches in diameter, and with comparatively flat curves, how much more difficult must it be to centre the six minute lenses of an achromatic object-glass one-eighth or one-twelfth of an inch in focal length; and if such

results were obtained by the correction of his error, how superior must the microscope be in which the concentric adjustment of its lenses is effected! While opticians, indeed, confine themselves to the use of only two kinds of glass, of different refractive and dispersive powers, we can hardly expect much improvement in the microscope, unless by the substitution of achromatic lenses in the eye-piece, and by an infallible method of centring each lens, and each group of lenses, in the instrument. The successful application of two pairs of adjusting screws to each of six lenses, and also to those of the eye-piece, may be a difficult task, but it is not beyond the powers of mechanism. It is very obvious that Dr. Wollaston's method of examining the centring of a triple object-glass is wholly inapplicable to the object-glass of a microscope. In submitting to examination an object-glass made by a distinguished optician, it was necessary to use a microscopic picture of the sun, and to examine the position of its images as reflected from the various surfaces of the lenses by means of a microscope, the object-glass of which was brought in contact with the outer lens of the object-glass to be examined. By separating the two object-glasses, I observed in succession a series of twenty-four images appearing and disappearing in succession. These images occupied different parts of the field, and I could not succeed by the most careful adjustment of the apparatus employed in placing them in the same axis. These images had various sizes, and were in various states of colour, some highly coloured, and some purely white. They had also various sizes, many with fine planetary discs, of different magnitudes; some like the smallest fixed stars which it was difficult to descry, and almost all of them exhibiting the most beautiful concentric diffracted rings when put out of focus. Two or three images often appeared in the same part of the field, in immediate succession, while similar pairs arose at a distance from each other. Although I often succeeded in uniting two or more of these images, yet the effect of this was to place others at a greater distance; and I had no hesitation in coming to the conclusion, that the lenses of the object-glass which produced these images were imperfectly centred. Having had occasion to see at the Paris Exposition, and more recently at Florence, the superior performance of Prof. Amici's microscopes, I cannot omit the present opportunity of urging philosophers and opticians, as I have often done, to correct the colours of the secondary spectrum by fluids or solids of different dispersive powers. Prof. Amici has done this. In his object-glasses, Nos. 1 and 2, of low powers, he employs five different refractive and dispersive substances. In his powers Nos. 3, 4, and 5, he employs five such substances; and in his highest power, No. 6, he employs six. In recommending, as I have often had occasion to do, the employment of diamond and other gems in the construction of compound as well as simple microscopes, I have been met with the objection that they are too expensive for such a purpose, and they certainly are for instruments intended merely to instruct and amuse; but if we desire to make great discoveries, to unfold secrets yet hid in the cells of plants and animals, we must not grudge even a few diamonds to reveal them. If Mr. Cooper and Sir James South have given a couple of thousand pounds for a refracting telescope, in order to study what have been miscalled "dots" and "lumps" of light on the sky; and if Lord Rosse has expended far greater sums on a reflecting telescope for analysing what have been called "sparks of mud and vapour" encumbering the azure purity of the heavens, why should not other philosophers open their purse, if they have one, and other noblemen sacrifice some of their household jewels to resolve the microscopic structures of our own real world;—to unravel mysteries most interesting to man; and disclose secrets which the Almighty must have intended that we should know?

On a new Polarizer, resulting from a Modification of the Prism of Nicol. *By* M. Léon Foucault, *Paris.*

When it is proposed to polarize in a complete manner a pencil of white light, the best means is to recur to the prism of Nicol; but if a pencil of a certain volume is to be acted on,—from four to five centimetres diameter, for example,—Nicol's prism becomes expensive and difficult to realize, on account of the scarcity of the beautiful specimens of the spar of Iceland. The cut adopted for the construction of the prism of Nicol entails necessarily a great cost of material. To have the prism entire,

a crystal of spar is required, whose longitudinal ridges are at least equal to three times one of the equal sides which terminate the bases. The piece is then cut from angle to obtuse angle by an inclined plane of 38° on the plane of their bases, and perpendicular to that of their smaller diagonals. The two surfaces thus obtained are polished and glued together with balsam of Canada, when a parallelopiped thus prepared is placed on a bottom uniformly lighted. On looking through the piece, a field of polarization is seen contained between two curved bands,—one red, the other blue,—which correspond with the direction of the limits according to which the ordinary and extraordinary ray are transmitted. These bands comprise an angular space of 32°, which makes Nicol's prism an analyser, applicable in all cases where the inclination of the ray, which it is desired to observe simultaneously, does not exceed 32°. But this angular extent of the field of polarization, which is sought for in the prism of Nicol, considered as an analyser, no longer presents the same interest when the apparatus is to fulfil the part of a simple polarizer; for then the action desired to be produced acts only, in general, on a pencil of light nearly parallel. So that there will be an advantage, in similar circumstances, in increasing the extent of the transverse dimension of the prism, even when the consequence would be a certain reduction in the extent of the angular field of polarization. Reflecting on the data of the question, I have in effect discovered, that we can modify the prism of Nicol in its cut, so as to diminish considerably the length without injury to its character of polarizer. I take then a parallelopiped of spar, whose longitudinal ridges equal only five quarters of one of the sides of the base. An inclined section of 59° on the plane of the bases, and the new surfaces, being polished, I put the two pieces in their natural position without fastening them, taking care to preserve between the new surfaces a little space, where the air penetrates, and which, with the proper incidence, determines the entire reflexion of the ordinary ray. Looking through a rhomb thus prepared—in other respects mounted like a prism of Nicol—there is still discovered an angular field of polarization; but the index of refraction of air being considerably below those of the two rays propagated by the spar, complete polarization only takes place in an extent of 8°, and the field it presents is found comprised between two red bands. The new combination then does not fulfil the conditions necessary to the formation of a good analyser; but when it is only required to polarize a pencil of solar light, whose extreme rays have an inclination but of half a degree, the prism, with the thin stratum of air and its eight degrees of field, more than suffices to polarize all the elements of such a pencil. This kind of polarizer is even in some respects preferable to the prism of Nicol, provided that the reflexion of the ordinary ray takes place under an incidence which sends it back almost normally to the intersection of its two lateral faces; this ray has no tendency to issue by the base and confound itself, as in Nicol's prism, with the extraordinary ray. Also, when the material of spar is very pure, it accomplishes the extinction of the pencil produced by an analyser in a complete manner on the whole extent of the transmitted pencil. It is likely that in cases where the prism of Nicol is employed as a polarizer, the new form will be preferred, since it produces an effect more complete, at the same time economizing nearly two-thirds of the mass of spar.

On a Telescope Speculum of Silvered Glass.
By M. Léon Foucault, *Paris.*

The astronomical refractor, compared with the reflecting telescope of the same dimensions, has always had the advantage of giving more light; the pencil of rays which fall on the object-glass passes through it for the most part, and is employed almost entirely in the formation of the image at the focus; while on the metal mirror a part only of the light is reflected in a converging pencil, which loses still more by a second reflexion being brought back towards the observer. However, as the reflecting telescope is essentially free from aberration of refrangibility, as the purity of its images depends only on the perfection of a single surface, as with regard to focal length it possesses a greater diameter than the refracting telescope, and thus partly regains the light wasted by reflexions—some observers continue to give it the preference, chiefly in England, over the refracting telescope for the examina-

tion of celestial objects. It is certain that at this moment, and despite the multiplied improvements in the manufacture of large glasses, the most powerful instrument directed towards the heavens is a telescope with a metal speculum. The telescope of Lord Rosse is 6 feet English in diameter, and its focal distance is 55 feet. Possibly the reflecting instruments would have gained the superiority, could the metal take as durable a polish—could it be as well worked as the glass, and were it not heavier. Placing thus in parallelism the two sorts of instruments, and discussing their respective qualities and defects, I finished by conceiving that the telescope with a glass would possess every advantage, if the mirror being once shaped and polished we could communicate to it the metallic brilliancy, in order to obtain from it images as luminous as those of the refracting telescopes. This thought, which at first appeared a fiction of imagination, was soon converted into a satisfactory reality. The glass being cut by an experienced optician, and thoroughly polished, is ready to be covered by Drayton's process with a very thin uniform coating of silver. This metallic coating, which when taken out of the bath in which it is formed is dull and dark, is easily brightened by rubbing with a skin lightly tinged wth oxide of iron, and acquires in a short time a very brilliant lustre. By this operation the surface of the glass is wholly of metal, and becomes vividly reflective, not exhibiting under severest tests the slightest alteration in form. To procure a disc of glass with concave surface perfectly finished, I applied to Mr. Secretan, who had the kindness to provide for me a clever workman. On the other hand, to be able to obtain a deposit of silver, I had recourse to the owners of the English patent, M. Power and M. Robert, who actually work the process in France, and who furnished me with the silvery solution, giving at the same time the fullest instructions how I might best succeed. My mirror being silvered, and having acquired a polish of steel, I formed a telescope of it of ten centimetres diameter and fifty centimetres focal length. This little instrument supports well the eye-glass, which magnifies 200 times, and compared with the reflecting telescope of one metre, gives a very sensibly superior effect. Wishing to learn the proportion of light usefully reflected by the layer of silver deposited on the glass, and afterwards polished, or, at least, to compare the intensity of a pencil of rays reflected by a surface thus prepared with that of one transmitted by an equal surface from the object-glass of a refracting telescope, I accomplished the matter without difficulty by means of a photometer with divisions, which I had employed on another occasion. The result of this operation ensures a decided advantage to the new telescope. The pencil of rays reflected on the silvered glass is equal to 90 per cent. of those transmitted through an object-glass of four partial reflexions; so that the new instrument avails itself of the overplus of light, which, on account of the greater diameter of the mirror, concurs efficiently to the formation of the focal image. Diameters equal, the telescope with glass is by one-half shorter than the other instrument; with equal lengths, it bears a double diameter, and collects three and a half times more light. Considered in another point of view, the new combination is distinguished in this, that it produces all its effect without the concurrence of those numerous conditions required to obtain a certain degree of perfection in any telescope, whether reflecting or refracting. The achromatic telescope, above all, requires that the constructor of it, at one and the same time, pay particular attention to the homogeneity of the two sorts of glass which form the object-glass, their refracting and dispersive powers, the combination of curves, the centring and the execution of four spherical surfaces. In the new telescope, on the contrary, the glass, serving not as a middle refractor, but only to support a very thin layer of metal, the homogeneity of the mass is by no means required, and the most ordinary glass of sufficient thickness worked with care affords a concave surface, which when silvered and polished furnishes of itself and by reflexion excellent images. There is one strong objection to the metal mirrors,—it is, that they become oxidized in time, and are tarnished by contact with the air. Eight months I have kept silvered mirrors, which have not yet undergone any sensible alteration. Will they preserve this state of perfection a still longer time? The experiment has not been sufficiently prolonged to decide one way or the other; but even should the lustre of the mirror become weaker, there is no difficulty in recurring to the same means for re-establishing it, by which it had been at first obtained. In fine, should the depth of the silver be altered, the

operation of depositing it is so easy and prompt, that it can easily be repeated. To resume, the new instrument, compared with the refracting telescopes, gives, at much less cost, more light, more distinctness, and is free, like the reflecting telescope, from all aberration of refrangibility.

On the Colour of Salts in Solution, each Constituent of which is coloured. By J. H. Gladstone, *Ph.D., F.R.S.*

It is a general law, that "all the compounds of a particular base or acid, when in aqueous solution, absorb the same rays of light;" hence it may be deduced, that when a coloured base and a coloured acid combine, the resulting salt will transmit only those rays which are not absorbed by either constituent, or in other words, only those rays which are transmitted by both. This was proved to be actually the case by a prismatic examination of compounds of chromic, permanganic, and carbazotic acids with copper, iron, nickel, uranium, and chromium. Though the compounds of chlorine, bromine, and iodine with hydrogen and most metals are colourless, the compounds of these halogens with gold, platinum, and palladium exhibit an absorption of light due to the halogen as well as that due to the metal. The same is true in respect to chlorides, bromides, and iodides of copper, iron, nickel, and cobalt, when these salts are dissolved in a minimum of water; but when more water is added, the colour changes, and the absorption due to the halogen no longer exists. In one or two of the cases examined a slight variation from the general law occurred; and ferrocyanide of iron forms a complete exception. The double chloride of platinum and copper shows the absorbent effect of all three constituents.

On the Effects of Heat on the Colour of Dissolved Salts. By J. H. Gladstone, *Ph.D., F.R.S.*

If a coloured salt be dissolved in water, heating the solution does not usually affect the colour of it. In not a few cases, however, the colour is rendered more intense, and altered somewhat in its character. Among the examples mentioned were ferridcyanide of potassium, meconate of iron, chloride and bromide of palladium. In other cases, heating the solution produces apparently a total change of colour: for instance, chloride of copper passes when heated from blue to green; chloride of nickel from a bluish to a yellowish green; sulphocyanide of cobalt, or chloride of cobalt dissolved in aqueous alcohol, from a pale red to a deep bluish purple. In all these instances heat causes the absorption of a larger quantity of rays by the solution; but this appears to depend sometimes upon some purely physical cause, at other times upon some chemical change. With ferridcyanide of potassium, and similar salts, a certain thickness of the heated solution produces precisely the same effect on the spectrum as an increased thickness of the same solution when cold. With chloride of copper, and similar salts, the somewhat dilute solution when heated produces the same effect on the spectrum as the same solution when concentrated and cold,—these salts being all of that character which is altered in colour by the addition of water.

On Improvements in the Optical Details of Reflecting Telescopes and Equatoreal Instruments. By Thomas Grubb, *M.R.I.A., Dublin.*

The author stated, that while the Earl of Rosse, by his achievements, had placed beyond doubt the practicability of producing specula for reflecting telescopes at once as perfect as could be desired, and as large as could be made practically useful, the achromatic object-glass had received but little increment of size; and though the Messrs. Chance, of Birmingham, had produced a pair of discs, of optical glass, of 29 inches diameter, yet these had been allowed to be transferred to another country, where the work of forming them into an object-glass was still to be effected. Four years had now elapsed since the production of these discs, and the refracting telescope may now be considered as being completely distanced in size by its competitor, the reflector. Under such circumstances, it was important, he conceived,

to give to the reflecting telescope every possible accession of improvement which the progress of art or science placed from time to time at our disposal. The two points of admitted inferiority of the reflector being, a greater liability to tarnish than glass, and less intrinsic brilliancy of the reflected pencil of light; the author had succeeded (so far as the small speculum of the reflecting telescope is concerned) in entirely obviating the former objection, and in very much lessening the other. Regardless of the failure of an attempt, made years since, to construct a reflecting telescope of glass surfaces quicksilvered, he concluded, from his own experience, that such surfaces could be made equally perfect with those of speculum metal; while by silvering (not quicksilvering) that surface required to reflect, a great increase of light would result, thus producing for the small reflector of the telescope a mirror as imperishable as glass, and, in reflecting power, approaching the transmitting power of a lens. The author explained why, instead of using this reflector in its simplest form, viz. that of a lens of equal thickness silvered on one side, he preferred an achromatized compound of two lenses, cemented and silvered, and exhibited such a compound, which, he stated, had on trial performed perfectly. He next proceeded to describe in detail his proposed application of the same principles to both small and large specula of telescopes (where such were of moderate dimensions), as also an improved form of the prism of total reflexion applicable to Newtonian telescopes of the largest dimensions. This latter is a prism of divergent or concave power made aplanatic, or at least achromatized, reducing the convergence of the rays coming from the large speculum, and also the size required for the prism in the same arbitrary proportion (two or three times being suggested); the required magnifying power being obtained by a proportionally lower eye-piece. The author next proceeded to discuss the respective merits of the several varieties of equatoreal mounting as applicable to large telescopes. The first variety, or long polar axis (biforked or not), he rejects from its necessarily great length and consequent unsteadiness. The second, or large-cone polar axis, supporting the telescope in a bifurcation prolonged beyond the upper bearing, he would also reject, from the enormous weight of such in proportion to the telescope carried,—4 tons being stated as the moving mass in the case of a telescope of only 8 inches diameter. The third, or German variety of construction, the author considers, in its general type, as preferable to all others; and he has therefore devoted much attention to its improvement. By a system of internal counterpoise, he has reduced the direction of the pressure of the declination axis (with its appendages, including the telescope and its counterpoise) to that of the centre of revolution of the polar axis, removed all end pressure of the declination axis, and supported all but a small fraction of these weights by anti-friction rollers. In this arrangement great steadiness is retained and freedom of motion attained. An instrument combining these principles and carrying a 12-inch achromatic of 20 feet focus, has but about 12 cwt. of material (including the telescope) to be moved; and this is effected by a force of about 1 lb. applied at the eye end. This instrument, contrasted with the 8-inch before mentioned, is (allowing for the difference in size) lighter in the proportion of about hundredweights to tons. The author, in conclusion, and aided by drawings, explained the general construction of an instrument of the German type which he had devised purposely for the proposed great southern telescope, and which construction had been selected by the Committee appointed by the British Association in reference to the same. In this instrument a telescope of the proposed diameter (viz. 4 feet), and the other moving portions of the instrument, are calculated at 19,000 lbs., moved by a force of 20 lbs., applied at a radius of 5 feet; the other proposed construction, which was that of the prolonged polar axis, being estimated at 45,000 lbs. moving weight, and requiring 750 lbs., or $37\frac{1}{2}$ times that of the author's construction for its movement.

On a Method of determining whether the Luminiferous Vibrations are Parallel or Perpendicular to the Plane of Polarization. By M. l'Abbé Moigno, *Paris.*

By a truly extraordinary *tour de force*, such as we find no other example of in the history of mathematics applied to physics, M. Cauchy, starting from two angles determined experimentally by Sir David Brewster, the principal angle of incidence and the

principal azimuth, succeeded, without any photometric experiment, in determining the quantity of light reflected from the surface of metals. Going even still further, M. Cauchy calculated this same quantity of light for all the incidences in cases where the primitive ray would be supposed to be decomposed into two polar rays at right angles, the one parallel and the other perpendicular to the plane of incidence.

Thus,—1st, indicating by I*i* the intensity of the reflected ray when it is polarized in a direction parallel to the plane of incidence, and by I*p* the intensity of the reflected ray when it is polarized perpendicularly to the plane of incidence, supposing the ray to fall under the principal incidence, and taking as unity the intensity of the incident ray, M. Cauchy found—

For silver	I*i* = 0·96	I*p* = 0·79
For mercury	I*i* = 0·94	I*p* = 0·46
For the metal of specula	I*i* = 0·90	I*p* = 0·36
For steel	I*i* = 0·85	I*p* = 0·23

2. Taking silver alone into consideration, but supposing the ray to fall by turns under the incidences 0°, 10°, 30°, 50°, 73°, 74°, M. Cauchy found that the quantities of light reflected were—

Under the incidences	0°	10°	30°	50°	73°	74°
I*i* =	0·548	0·553	0·596	0·693	0·814	0·859
I*p* =	0·548	0·543	0·499	0·402	0·261	0·232

This being settled, the following is the mode of reasoning, by which, we believe, all doubt may be removed as to the truth of the hypothesis which supposes that the luminous vibrations are perpendicular to the plane of polarization, and as to the falsity of that according to which the vibrations are parallel to this plane.

I. Of the two rays polarized at right angles, which we have hitherto considered, one has its vibrations parallel, and the other has them perpendicular to the plane of incidence and to the indication of this plane upon the plane of reflexion.

If we ask ourselves which of them must be least extinguished in the act of reflexion, which, when reflected must exhibit the greatest intensity, we shall answer without hesitation, that of which the vibrations are parallel to the plane of the reflecting surface, as it penetrates less into the metallic medium, and undergoes less of its influence. On the other hand, M. Cauchy has proved that the ray I*i*, polarized in a direction parallel to the plane of incidence, is that which is most reflected: consequently it is for this ray I*i* that the vibrations are parallel to the reflecting surface, or to the plane of reflexion; but vibrations parallel to the reflecting surface are at the same time vibrations perpendicular to the plane of incidence, and consequently perpendicular to the plane of polarization, which for the ray I*i* coincides with the plane of incidence; therefore for the ray I*i* polarized in the plane of incidence the vibrations are perpendicular to the plane of polarization. If we reasoned upon the ray I*p*, we should also say that it is the ray which is reflected with the least intensity, therefore it is that of which the vibrations are oblique to the reflecting surface, and at the same time perpendicular to the indication of the plane of incidence,—therefore, for the ray polarized perpendicularly to the plane of incidence, the vibrations are parallel to that plane, or perpendicular to the plane of polarization.

II. Of the two rays polarized at right angles, one is of such a nature, that as the incidence increases, the intensity after reflexion remains very nearly constant, and increases very little in proportion as the incidence increases; the other, on the contrary, is such, that its intensity after reflexion goes on diminishing more and more. Now is it not evident that the ray which must sensibly retain the same intensity after reflexion, is the ray of which the vibrations are parallel to the plane of reflexion; that, on the contrary, the ray which becomes extinguished by degrees when the incidence increases, is the one whose vibrations are in the plane of incidence, perpendicular to the direction of propagation, and to the intersection of the planes of incidence and reflexion; since these vibrations, being at first parallel to the plane of reflexion, erect themselves by degrees when the incidence increases, and form with the plane of reflexion an angle which becomes larger and larger, until they become perpendicular under the incidence of 90°? Now from the formulæ of M. Cauchy, the reflected ray of which the intensity is perceptibly constant, and increases slowly in proportion as the incidence increases, is the ray I*i*; therefore it is for this ray that

the vibrations are parallel to the plane of reflexion, and perpendicular to the plane of incidence, and consequently to the plane of polarization, which for this ray Ii coincides with the plane of incidence. According to M. Cauchy, also, the ray which is gradually extinguished in proportion as the incidence increases, is the ray Ip ; therefore it is for this ray that the vibrations, always perpendicular to the direction of propagation and to the intersection of the planes of incidence and reflexion, are in the plane of incidence, and consequently perpendicular to the plane of polarization, which is perpendicular to the plane of incidence. Therefore in all cases the luminous vibrations are perpendicular to the plane of polarization.

Mr. Stokes has raised an objection to this demonstration, which appears to us to fail. He says that M. Cauchy has deduced his numbers from a theory which assumes as its starting-point, the hypothesis that the vibrations are perpendicular to the plane of polarization; but there is nothing to prove that in this case, as in many others, we do not arrive at the same result by starting from the opposite hypothesis. We do not deny that this may be the case; but in order that our reasoning may subsist in its full extent, it is sufficient that the numbers of M. Cauchy should be considered as numbers obtained by photometric experiments. Now this is certainly the case, for these numbers undoubtedly agree with all the known results of photometric experiments. As soon as they are admitted as natural numbers, no objections can be raised to our mode of reasoning.

Electricity, Magnetism.

A Mathematical Investigation of the Proportion between the Length required for an Electric Telegraph Cable and its Specific Gravity. By Captain Blakely.

The author showed, by the principles of the composition of motion, as a telegraph wire was paid out from a ship, the velocity which gravity would give it would soon become uniform by the resistance of the water as its parts descended; therefore, the descending part of the cable from the advancing ship to the part of the cable which had reached and was supported upon the bottom, and which he showed in very deep water, say two miles or more, might stretch back six or more miles from the ship. Now, unless a great strain were kept on the brake in the ship where the cable was paying out, a strain, which in the case of the Atlantic cable had caused it to part, it was obvious from this demonstration that there must always be what the sailor termed "slack" in the cable when it reached and lay on the bottom, for the inclined length of the rope was always longer than the horizontal length of the bottom on which it was intended to lie. The author then proceeded to estimate, by mathematical formulæ, and numerically, the exact proportion of these in several supposed depths of soundings, rapidity of paying out, and specific gravity of the cable; and came to the conclusion, that the only way of lessening an evil, which must never be expected to be entirely got rid of, was by increasing the speed of the vessel paying out the cable, and diminishing the specific gravity of the cable itself, so that it should sink gently to its final position.

On the Electro-dynamic Induction Machine. By the Rev. Professor Callan, *of Maynooth College.*

After stating that he had discovered the induction coil in 1836, that in 1837 he had devised an instrument for getting a rapid succession of electrical currents from the coil, and that thus he had completed the coil in 1837, as a machine by which a regular supply of electricity might be furnished, the author said that he would lay before the Association the results of a long series of experiments on the induction machine. The first of these results is a means of getting a shock directly from the armature of a magnet at the moment of its demagnetization, by using, not a solid piece of iron,

but a coil of very fine insulated iron for the armature of an electro-magnet, between the poles of which the coil would fit. When the helix of the magnet is connected with a battery, the armature is magnetized on account of its proximity to the magnetized iron; and when the battery connexion is broken, if the ends of the insulated iron wire be held in the hands, a shock will be felt. The second result is the discovery of the fact, that if iron wires be put into a coil of covered copper wire, the ends of which are connected with a battery, and if another coil be connected with the same battery, the quantity of electricity which will flow through the latter will be greater when the first coil is filled with iron wires than when they are removed. The third result is, a core for the primary coil, which consists of a coil of insulated iron wire, and which has five advantages over all the cores in common use. First, there is no complete circuit for any electrical current excited in any section of the core, because all the spirals of the coil are insulated from each other, and no spiral returns to itself. In the common cores, even when the wires are covered with thread, there is a complete circuit for every current induced in each section of every wire. Secondly, the currents in the various sections of the iron coil do not oppose each other; but the currents in each section of every wire of the common cores are opposed by the currents flowing in the surrounding wires. Thirdly, in the iron coil all the currents in the various spirals flow in the same direction, and form one strong current, which may be used by connecting the ends of the coil with any body to which we wish to apply its force. But in the common cores all the currents in the sections of each wire remain within the wires, and cannot be used. Fourthly, the effect of the condenser on the currents produced in the iron core can be ascertained when an iron coil is used, but not with the common cores. By using an iron coil as a core, it is found that the condenser increases the intensity of the currents induced in the core. Fifthly, the ends of the iron coil, used as a core, may be connected with the coatings of a Leyden jar, and then the sparks from the coil are diminished in length, but increased in brightness. By the use of cores consisting of coils of insulated iron wires, electrical currents of considerable quantity and intensity may be obtained. These currents of quantity and intensity may answer for working the Atlantic telegraph, and for producing the electric light. Besides the cores just described, and the common core, Prof. Callan used three other kinds of cores; viz. a flat or elliptical bundle of wires; a core made by coiling uninsulated iron wire on an iron bar, and a core consisting partly of a bundle of iron wire, and partly of a coil of insulated iron wire. The fourth result of his experiments is a new mode of insulation, in which imperfect insulation is used when imperfect insulation is sufficient, and perfect insulation is employed where such insulation is required. The advantage of this mode of insulation is, that each spiral in the secondary coil is brought nearer to the other spirals, as well as to the primary coil and core, than it can be in the common method of insulation, without at all diminishing the efficiency of the insulation. A coil in which the secondary wire was iron, and insulated in the manner described, was shown to the meeting, which, with a single cell, 6 inches by 4, gave sparks half an inch long without a condenser. The insulation of the large condensers made by Prof. Callan, in which the acting metallic surface of each plate exceeded 600 square feet, gave way before the coil which he exhibited was made; and therefore he could not say what the length of the sparks would be with the aid of a condenser. But were a condenser of the proper size to have the effect of increasing the sparks in a thirtyfold ratio, as in Mr. Gassiot's great coil, the length of the sparks produced by Prof. Callan's coil with a single cell should be 15 inches. The outer diameter of the coil was about 4 inches, its length 20 inches, and the length of the secondary coil about 21,000 feet. The fifth result is, a contact-breaker in which the striking parts are copper, and which acts as well as if they were platina. The sixth result is a more satisfactory explanation of the condenser, which is confirmed by the effect of the condenser on the electrical currents produced in the core. The last result consists in the discovery of some new facts relating to the condenser, from some of which it follows, that the ordinary mode of making the condenser is defective; for condensers are generally made so that the entire surface of each of the metallic plates must act. But the condenser for every coil should be constructed in such a way, that a small, or a considerable part, or the whole of the surface of each plate may be applied to the coil. For a large condenser which would make the effect of a coil ex-

cited by a single cell less than it would be without a condenser, will increase the effect of the same coil, when it is connected with a battery of ten or twelve cells.

On controlling the Movements of Ordinary Clocks by Galvanic Currents. By John Hartnup, *F.R.A.S.*

Since the application of electricity to the purposes of the telegraph, various methods have been employed for working clocks at distant stations by a normal clock at an observatory, or by causing one clock in a large establishment to work several sympathetic clocks in different parts of the building. The advantage of being able to make several clocks show the same time as a normal clock regulated by astronomical observations, or by the transmission of time signals from an observatory, must be admitted to be great; but those who have had much practical experience in the matter are aware of the serious drawback which, in spite of every precaution, will occasionally arise from failure in the galvanic current, and which necessarily causes all the sympathetic clocks to stop. We think, therefore, that the members of the British Association for the Advancement of Science will be gratified to hear of an invention which sacrifices nothing in point of accuracy, and which is, nevertheless, perfectly exempt from the objection to which we have alluded.

For the discovery of this simple and very beautiful method, we are indebted to Mr. R. L. Jones, of Chester; and the first application of it to a large public clock was to that of the Liverpool Town Hall. This clock being appealed to by the merchants on change as the standard of time, had subjected them to great inconvenience by its irregular performance, and at my recommendation the plan of Mr. Jones has been adopted with perfect success. The clock in its present state, with the improvements which have been made, differs in no respect from an ordinary old turret clock, except that the pendulum-bob is a hollow electro-magnetic coil, which passes around permanent magnets at each oscillation. At each transmission of a current from our normal clock at the Observatory, the coil itself becomes a magnet, and the attraction or repulsion between it and the permanent magnet prevents the pendulum from oscillating except in strict conformity with the pendulum at the Observatory. The wire which connects the Town Hall clock with the clock at the Observatory is about one mile in length, and the controlling power is so great, that a single cell of a Smee's battery charged with very weak acid is sufficient to control the movements of the Town Hall clock, even when the pendulum is lengthened or shortened so as to make it lose or gain several minutes a day when not under the control of the clock at the Observatory. In practice, however, the pendulum is regulated to correct time as near as possible, so that in the event of the current failing, the clock will not only continue to go, but it is liable to the errors only of an ordinary clock; and as an error so small even as a fraction of a second is sufficient to show that the current is not controlling, the fault may be detected and the remedy applied before the public are subjected to any inconvenience.

By this method therefore it is quite practicable to make all the public clocks in a town, or any number of clocks in a large building, strike, or keep the same time to a fraction of a second, without the risk of inconvenience by failure of the electric current, since all the clocks would go as ordinary clocks should the current fail.

This method of controlling the pendulum of a large public clock has been in operation at Liverpool for several months past, and the public have an opportunity each hour of the day of witnessing the efficiency of the method. In the office window of the Magnetic Telegraph Company, which is within a few yards of the Liverpool Town Hall, there is a sympathetic seconds clock, the face of which is exhibited to the public. This clock is worked by our normal clock at the Observatory; and as the seconds' hand, at the end of each hour, falls upon the sixtieth second, the first blow of the hammer of the Town Hall clock breaks upon the ear, much to the admiration and astonishment of a large number of persons who congregate daily to witness this novel performance.

The normal clock at the Observatory is an ordinary astronomical clock, the contact-springs of which are so slight as not to interfere sensibly with its performance. It will be seen, therefore, that by placing a good astronomical clock in any building, a turret or any other clocks may be connected and their movements controlled by it, and a degree of accuracy secured which has hitherto not been attained.

On the Amount and Frequency of the Magnetic Disturbances and of the Aurora at Point Barrow, on the Shores of the Polar Sea. By Major-General Sabine, *Treas. R.S.*

Point Barrow is the most northern cape of that part of the American continent which lies between Behring's Strait and the Mackenzie River. It was the station of H.M.S. 'Plover' from the summer of 1852 to the summer of 1854, and to Captain Maguire, now in the Section, and to the officers of that ship, they were indebted for the very valuable series of observations which he was now about to lay before the Section, and in part discuss.

They were furnished with supplies of provisions, &c. for Sir John Franklin's ships, had they succeeded in making their way through the land-locked and ice-encumbered channel, through which they sought to effect a passage from the Atlantic to the Pacific. In this most dreary and otherwise uninteresting abode Capt. Maguire and his officers happily found occupation during seventeen months unremittingly, in observing and recording every hour the variations of the magnetic and concomitant auroral phenomena, in a locality perhaps one of the most important on the globe for such investigations. Their observatory, placed on the sand of the shore, which for a long tract nowhere rose much more than 5 feet above the sea, was constructed of slabs of ice, and lined with seal-skins throughout. The instruments had been supplied by the Woolwich establishment, together with the requisite instructions for their use; and the observations were made and recorded precisely in the same manner as those of the Colonial magnetic observatories. These were sent by Capt. Maguire to the Admiralty, and were in due course transmitted to General Sabine, by whom they were subjected to the same processes of reduction as those made in the Colonial observatories.

The author then exhibited to the Section six diagrams, containing the results of this discussion, giving the reduced observations at each of the hours of the twenty-four. A sufficient body of the larger disturbances having been separated from the rest, it was found at Point Barrow as elsewhere, wherever similar investigations had been made, that in regard to the frequency of their occurrence, and the average amounts of easterly and westerly deflections, the disturbances followed systematic laws depending on the hours of solar time. The laws of the easterly and westerly deflections were also found at Point Barrow, as elsewhere, to be distinct and dissimilar. The author explained how these observations were separated from the rest, for the purpose of this investigation. Upon instituting a comparison between the disturbance laws at Point Barrow and Toronto, it was found that the laws of the deflections of the same name at the two stations did not correspond; but, on the other hand, that there existed a very striking and remarkable correspondence between the law observed by the easterly at Point Barrow and the westerly at Toronto, and between the law of the westerly at Point Barrow and easterly at Toronto; this correspondence was shown to exist not in slight or occasional particulars only, but throughout all the hours in well-marked characteristics of both classes of phenomena; and from the correspondence in the hours at which opposite disturbance deflections prevail, it follows that the portion of the diurnal variation which depends upon the disturbances has opposite, or nearly opposite, characteristics at the two stations. The importance of eliminating these disturbances from the regular march of the solar variation was then pointed out; for when the diurnal variation is derived from the whole body of observations at Point Barrow, retaining the disturbances, the westerly extreme of the diurnal excursion, which, as is well known, occurs generally in the extra-tropical part of the northern hemisphere a little after 1 P.M., is found to take place at 11 P.M.; but when these larger disturbances are omitted, the westerly extreme is brought back to the same time as elsewhere, viz. 1 P.M.; and the author suggested the probability that the anomalies which have sometimes been supposed to exist in the turning hours of the solar diurnal variation in high latitudes may be susceptible of a similar explanation. It appears, then, by a comparison of the Point Barrow and Toronto observations, that in the regular solar-diurnal variation the progression at the two stations is similar, the easterly and the westerly extremes being each reached nearly at the same hours, whilst in the disturbance diurnal variation this progression is reversed. Another distinction exists in their magnitudes, which are

found in the solar-diurnal variation to be as nearly as may be in the inverse ratio of the values of the horizontal force at the two stations (which is the antagonistic force opposing all magnetic variations), whilst on the other hand the increase in the range of the disturbance variation is many times greater than it would be according to the same proportion. It would appear, therefore, that the energy of the disturbing force must be much greater at Point Barrow than at Toronto.

The author then proceeded to point out the concomitant occurrences of the auroral manifestations. The observers noted at each hour whether or not there was an aurora visible: from 11 A.M. to 3 P.M. no auroral displays were ever observed; but the number of them was found progressively to increase from 3 P.M. to 1 A.M., and then again in regular progression to decrease to 0, at 11 A.M. The frequency of the occurrence of the aurora may be judged of, when it is shown that during six months,—December, January, and February of 1852–53, and the same of 1853–54, —the aurora was seen six days out of every seven. The hour of the day at which no auroral display is ever observed corresponds with the minimum of westerly disturbance, while the maximum of both is found at the same hour of westerly disturbance, viz. 1 A.M. The frequency of the aurora, also, and the amount of westerly deflection of the magnet also accord; whilst on the other hand, the auroral hours appear to have little or nothing in common with the turning hours or the progression of the easterly deflections.

When Sir John Franklin was going out on the expedition which deprived his country of the invaluable services of himself and his brave companions, he had been furnished by the Admiralty with instruments carefully adjusted and compared with standards, and with full instructions for their use, and for the making and recording hourly magnetic observations in the several stations he might occupy in these seas; and in the last letter which had ever been received from him, he had expressed his determination to put up those instruments at the several stations at which he should winter. Now when his ardour in these pursuits and that of Captain Crozier, the second in command, and the other officers, were taken into account, there could remain no doubt that such observations had been made and recorded, and that these records may still exist if the ships themselves have not been destroyed. Parties quitting the ships with the prospect before them of a long and perilous journey to the Hudson's Bay settlements would not be likely to charge themselves with such records, but would leave them, well secured, to be found by those who they might naturally expect would be sent to search for them. He had therefore no doubt that if the ships of Sir John Franklin were still in existence, the records of more than one winter's observations would be found in their cabins; and this was one of the reasons why men of science were so anxious to have the ships carefully looked for; it was a duty to the memories of those who had sacrificed their lives in procuring these and other valuable results, to have them recovered if possible.

Brief Account of the Construction and Effects of a very Powerful Induction Apparatus, devised by Mr. E. S. Ritchie, *of Boston, United States. By* Professor W. B. Rogers.

In this the secondary coil is formed by winding the wire in such manner as to make a series of flat spirals, having each the thickness of a single wire, and thus building up the coil by thin transverse strata. The primary coil is covered by a gutta-percha tube, and this by a closely fitting bell-glass, knobbed at the upper end, and having a widely expanded lip below. Over the whole is placed the secondary coil. By this arrangement the discharge between the core and the secondary coil is effectually prevented. Very perfect means are used for preventing any discharge within the secondary coil, between its different parts. With a secondary coil of 30,000 feet of wire, No. 34, and using one Bunsen cell, this apparatus gives a spark 6 inches in length. When the coil is increased to 50,000 or 60,000 feet, and four cells are used, the spark is lengthened to upwards of 10 inches, and has been passed continuously through an interval of $10\frac{5}{8}$ inches. The primary coil is formed of No. 9 wire, and is about 80 feet in length. The condenser, made of tinfoil separated by oiled silk, has a surface in this larger apparatus of about 30 feet. Prof. Rogers referred to the very superb phenomena produced by the passage of the cur-

rent through an exhausted tube of great length and diameter, and to those exhibited by the beautiful arrangement known as Gassiot's Cascade, which, with other phenomena of electrical light, were developed by this apparatus with a splendour perhaps never before equalled.

Researches on the Correlation of Dynamic Electricity and the other Physical Forces. By M. Louis Soret.

Introduction.

Suppose an electric circuit composed, for example, of a voltaic battery, the poles of which are united by a conductor. Suppose, in the first place, that all parts of this circuit are sufficiently distant from any other conducting or magnetic body, that the current cannot exert any exterior action. The facts may then be represented in the following manner. In the battery, a chemical action, the primary source of force, is set up. If the two poles be disunited, the chemical action can nevertheless take place; this production of force is manifested by heat evolved in the battery itself. If the poles be united by a conductor, a part of this force is converted into electricity; it manifests itself without the battery in the conductor, where it again becomes transformed into heat. According to M. De la Rive and M. Favre, the sum of the quantities of heat disengaged in the battery and in the rest of the circuit, has a constant value for the same amount of chemical action, a law which is perfectly in accordance with the principle of the conservation of forces. This quantity of active force, which is usually manifested in the form of heat, may be called the *interior work of the circuit.*

Now suppose the current to act upon bodies external to its own circuit; we know that it may produce currents of induction, magnetization, &c., forces which may themselves be converted either into heat or into mechanical work. This new quantity of active force may be called the *exterior work of the circuit.*

If it were to be supposed that nothing was changed in the primary circuit when it had to exert an exterior action, that the interior work has its value whether or no the current produces exterior work, this would lead us to admit a *creation of force,* and to place ourselves in complete opposition to the fundamental principles of mechanics.

What are the changes into the phenomena produced in the interior of the circuit when exterior work is produced? in other words, how is the conversion of force then effected? This is the question, the investigation of which I have set before me.

We are already aware, principally from the researches of M. Jacobi, that when mechanical work is produced by means of electricity with the aid of an electro-magnetic machine, the current employed diminishes in intensity; with this diminution of intensity, a diminution of the heat evolved in the circuit must necessarily correspond. But it appears to me that the explanation is far from being satisfactory. In fact, at the same time that the intensity of the current is weakened, the chemical action is also weakened; and according to Faraday's law, which appears to be now well established, it is admitted that the amount of chemical work produced in the battery is always proportionate to the intensity of the current. It results from this, that, as regards the chemical action, we may perfectly assimilate a current whose intensity is weakened because it produces exterior work, with another current which exerts no exterior action, but of which the intensity is less. We may therefore conceive two circuits, one only producing interior work, the other producing exterior work in addition, but having both the same intensity, and consequently consuming the same quantity of zinc in the two batteries to which they owe their origin; can we suppose that the interior work will be the same in both circuits? Evidently not; this again would be to admit a creation of force. A change, for example, a diminution in the heat evolved, must supervene, either in the part of the circuit which exerts the exterior action by induction, or in the battery itself; or else Faraday's law ceases to be correct in this case.

I am far from having arrived at the solution of this question; and for the present I must confine myself to the investigation of some of its elements.

First Memoir.—*On the variations of intensity undergone by the electric current when it produces mechanical work.*

When an electric current is employed in setting any machine in motion, it under-

goes variations of intensity as soon as there is a relative displacement of the parts of the apparatus which attract or repel each other under the influence of the electricity. This phenomenon may be explained by the production of currents of induction in the conductor itself, in which the principal current is propagated. M. Jacobi has been the first to insist upon this point in different memoirs. The simplicity of the formulæ at which he arrived has been contested by M. Marié Davy (Comptes Rendus de l'Acad. des Sciences, 1855). I was of course obliged to attend to this subject, and I shall give a brief summary of the results of this investigation, results which are for the most part well known or easy to foresee, but which have not perhaps been exhibited in a sufficiently general manner, and of which all the consequences have not been examined.

Part I.—The phenomena which are here in question may be summed up in the following manner:—*When an electric current causes the attraction of two pieces of an apparatus, if these two pieces, yielding to this attraction, are set in motion, a diminution of the intensity of the current is observed;* and inversely, *when these two pieces which mutually attract each other are compelled to move in a direction opposed to that which the attraction tends to give them, we observe an augmentation of the intensity of the current whilst this movement is being effected.* This law appears to flow from the principle of Lery upon induction. I have verified it experimentally in four principal cases, in which a movement may be produced by the action of the current. I have also examined two other cases which do not answer directly to the enunciation of the law.

Most frequently these variations of intensity cannot be proved by the direct measurement of the current by means of a galvanometer, for they are too small in proportion to the total intensity; it is necessary to have recourse to a more delicate method, such as that employed by Wheatstone, Svanberg, &c., which has been sometimes designated by the name of the method of the *galvanic bridge*; at other times, especially when permanent magnets entered into the composition of the apparatus, it was necessary to be satisfied with proving the presence of a current of induction in a conducting wire suitably arranged.

The four principal cases which I have investigated are the following:—

1. Attraction of a piece of soft iron by an electro-dynamic coil; each time that the piece of soft iron penetrates into the interior of the coil, or emerges from it, a diminution or an augmentation of the current is observed.

2. Attraction of a piece of soft iron by an electro-magnet. The law is easily verified, even without the employment of the galvanic bridge, if a strong electro-magnet be used.

3. Mutual attraction of two coils, of which one can penetrate into the interior of the other. The variations of intensity are very slight.

4. Rotation of magnets by currents, and of currents by magnets. The intensity of the current is weaker when the apparatus is in motion under the influence of the current; it is stronger when it is forced to take a rotatory movement opposed to that which it would naturally take. These variations of intensity, which are very slight, arise from currents of *axial* induction, according to the denomination of M. Matteucci.

The secondary cases, which I have also studied, are,—

5. Attraction of an armature of soft iron by a permanent magnet. If the permanent magnet be surrounded by a coil, of which the extremities are in communication with a galvanometer, the latter shows, at the moment when the armature is attracted, a current of which the direction is the same as that which would be produced by a momentary diminution of the magnetism of the magnet. When the armature is pulled away, the current is in the opposite direction, as if there were an augmentation of the magnetism. These facts may be considered as confirming the law enounced.

6. Magnetism of rotation. It is well known, that when a sphere of copper is made to turn rapidly between the poles of an electro-magnet, currents of induction are developed in the sphere which present a considerable resistance to the movement of rotation. The motion of the sphere of copper is always contrary to that which the forces emanating from the electro-magnet tend to impress upon it; but these only originate when the movement takes place. If the law were still applicable in

this case, we ought to find a permanent augmentation of the intensity of the current as long as the sphere is in rotation. Different causes, amongst others the concussion which inevitably accompanies the rapid motion of the sphere, render the experiments very difficult. The following, however, are the results which I have obtained. When the sphere is set in rotation, as long as its rapidity continues increasing, a current of induction is developed, and this being added to the primitive current, slightly increases its intensity; when the movement of the sphere is uniform, the intensity again becomes the same as when the sphere was without motion; lastly, when the rotation becomes slower, the intensity is slightly diminished.

This case, therefore, does not come under the ordinary rule, which is accounted for because we cannot suppose that the current really produces any mechanical work: it acts like a force which would tighten a check; the resistance which the sphere experiences is analogous to a friction, and becomes converted into heat, according to the experiment of M. Foucault.

PART II.—In his researches upon the theory of electromotors, M. Jacobi has only occupied himself with the case in which the movement of the machine takes place in he natural direction. But nothing in the formulæ which he has given prevents their application to the case in which the machine is compelled to take a movement opposite to that which it tends to take under the influence of the electric forces. It is sufficient to give a negative value to the rapidity v. We then arrive at singular consequences.

In this case, the current of induction which M. Jacobi has called the *counter-current*, would become negative, that is to say, it would be in the same direction as the principal current, consequently the total current would be stronger whilst the machine is animated by a negative rapidity than when it is stopped.

Giving the rapidity a negative value, $\frac{\rho}{\kappa\beta^2}$, the total current would acquire an infinite intensity (formula 10 of M. Jacobi, 'Annales de Chimie et de Physique,' xxxiv. p. 451). Now this rapidity would not be very great. At the same time that the intensity of the current would become infinite, the mechanical work which it would be necessary to apply to the machine to give it this rapidity would itself become infinite (formula 19). From this it would follow, that by causing the machine to move in a direction opposite to its natural movement, the intensity of the current might be augmented indefinitely, and consequently mechanical work might be unlimited, converted into electric current.

Lastly, on this negative rapidity being still more increased, the current would change its direction.

It is useless to dwell upon the theoretical and practical importance which would be possessed by these consequences if they were realized. *A priori* we might think that it was impossible they should be absolutely verified, for the laws upon which the calculation is founded have been determined between certain limits and would cease to be correct if we passed those limits; moreover, electro-magnetic machines present, in their construction, certain obstacles which would prevent the absolute realization of these phenomena.

But, on making the experiment, far from seeing the intensity of the current indefinitely increased, when a reversed motion is given to the machine, we observe that the current is weakened almost as much as if the movements were effected in the normal direction. Thus, in an experiment made with a small electro-magnetic machine, constructed by Froment, the needle of a galvanometer deviated 57° when the machine was kept still; on setting the machine in motion so that 242 revolutions in a minute were recorded, the deviation fell to 30°; and on making it move in the opposite direction with the same rapidity, the deviation was 32°.

The results differ so widely from the deductions of calculation, that we must necessarily admit the inexactitude of the formulæ.

We have already said that M. Marié Davy had disputed them; he has indicated two elements which have been neglected in the calculation, namely, the *electrical inertia* proper to conductors, and the inertia which arises from these conductors being rolled in a spiral, in such a way that the turns of the spire act upon each other by induction. M. Jacobi has also neglected a still more important element, which M. Marié Davy has perhaps recognized and indicated in a recent memoir presented

to the Academy of Sciences, of which the title alone is mentioned in the 'Comptes Reudus.' This is the induction which magnetization must produce at the moment of the closure of the circuit: as soon as the current traverses the coils of a machine, the iron nucleus which they contain becomes magnetized, and this magnetization must produce an energetic current of induction in a direction opposed to that of the primitive current. When the circuit is interrupted, the demagnetization tends to produce a direct current of induction; but it cannot propagate itself, because the circuit is interrupted. The two effects therefore do not compensate one another.

However, I shall refer to these experiments, which show very clearly the necessity of taking this element into account.

1. A small electro-magnetic machine made by Froment was employed. It consists of a wheel furnished with six pieces of soft iron passing successively before the poles of three horseshoe electro-magnets. The axle which bears this wheel, also bears the commutator. The wheel and the pieces of soft iron were removed, leaving the axle and the commutator in their places. Of course the machine could no longer progress of itself, but the axle could be made to rotate, by transmitting to it in a suitable manner the motion of a wheel turned by a handle. There were then produced in the electro-magnets, alternations of magnetization and demagnetization similar to those which take place when the machine is in motion under the influence of the current. When the current is passed without the axle being set in rotation, the deviation of the galvanometer was 48°; then on setting the axle in motion so as to make 408 turns in a minute, the deviation fell to about 30°; when the rapidity was increased, the deviation diminished still more.

Thus without the production of any mechanical work by the machine, and without the development of those counter-currents arising from the approximation of pieces by mutual attraction, we see that the current is considerably diminished. This result appears to me to be perfectly incompatible with the calculations of M. Jacobi.

2. A circuit was formed, consisting of a battery, a watch-work interrupter, and a coil into which a cylinder of soft iron might be introduced at pleasure. A magnetized needle placed below a portion of the current deviated 32° when the iron cylinder was not put into the interior of the coil; but as soon as it was introduced, the deviation fell to 25°.

3. By means of a battery motion was given to an electro-magnetic machine, the movement of which was produced by the magnetization and demagnetization of a single electro-magnet, in such a way that the current was interrupted in the whole circuit during the period of demagnetization. The circuit also included a coil of considerable resistance; the moment a cylinder of soft iron was introduced into this coil, the motion of the machine was notably retarded.

These three experiments show in a striking manner the loss of force which is caused by the employment of non-continuous currents in electro-magnetic machines. There is in this case an analogy with ordinary steam engines, in which a great part of the force which might be produced by the heat is uselessly employed. Better results in this respect would doubtless be obtained, if we could succeed in constructing machines of a certain force, founded upon the principle of the rotation of currents by currents, or *vice versâ*. But hitherto these machines have had too little power to allow of their being employed as motors.

Second Memoir.—*On the heat evolved by the current in a conductor, arranged so as to produce exterior work.*

I have already stated that when a circuit produces exterior work, a change must be produced in the interior work, that, for example, there must be a diminution in the heat evolved either in the part of the circuit which effects the exterior action by induction, or in the battery itself. The former of these suppositions has been investigated in this memoir.

The question, then, is to know, if a coil, for example, when traversed by a current, undergoes the same elevation of temperature when it exerts no exterior action, and when it exerts one, such as the alternations of magnetization and demagnetization which it produces upon a nucleus of soft iron when the current is not continuous.

The method adopted consists in arranging, in the same circuit, two coils, each

placed in a calorimeter, which measure the quantities of heat evolved. We determine, in the first place, the relative quantities of heat evolved in the two coils when neither of them exerts any exterior action. The apparatus is then arranged so that one of the coils may produce exterior work, and we see whether the relative quantities of heat remain the same.

The coils employed were of copper wire covered with silk; they were placed in calorimeters filled with rectified oil of turpentine, a non-conducting liquid, of which the elevation of temperature was determined. The calorimeters first employed were brass vessels, of which the annular form would allow of the introduction into the interior of the coil, of a cylinder of soft iron, or of the body upon which the exterior action was to be exerted. Subsequently glass calorimeters were made use of. The calorimetric methods of M. Regnault were adopted.

In operating with a brass calorimeter and a cylinder of soft iron in the interior of the coil, currents of induction are developed in the walls of the calorimeter itself, which evolve a great quantity of heat; the experiments made in this way consequently present a very considerable source of error, but they demonstrate that the exterior work exerted by the current is very considerable; in fact, the excess of heat betrayed by the calorimeter containing the soft iron, sometimes rises to $\frac{1}{3}$th of the heat evolved in the coil itself.

With glass calorimeters, after the elimination of numerous causes of error which render these experiments very delicate, a negative result was obtained, that is to say, the relative quantities of heat evolved in the two coils were found not to be modified when one of these coils produced an action exterior to itself by induction. The following are the numerical results of the last experiments which were made:—

Elevations of temperature of the calorimeter containing the coil which exerted an exterior action.		
Observed.	Calculated.	Differences.
4·990° C.	4·978° C.	+ 0·011° C.
5·647° ,,	5·653° ,,	− 0·006° ,,
5·202° ,,	5·191° ,,	+ 0·011° ,,
4·120° ,,	4·088° ,,	+ 0·032° ,,

From this we must conclude that the heat evolved is the same in the two cases, and that it is not in the part of the current which exerts an exterior action that we must seek for the modification which the interior work must undergo under these circumstances.

Description of an Arrangement of Grove's *Battery.* *By* G. Johnstone Stoney, *A.M., M.R.I.A.*

The earthenware cells in this arrangement were the ordinary flat cells commonly used for Grove's battery, consisting of flat porous cells containing nitric acid, placed within outer cells of glazed earthenware containing acidulated water.

A sheet of platinum foil hangs into each cell of nitric acid, and on either side two parallel plates of zinc stand in the acidulated water of the outer cell. A stout copper wire effects the necessary connexion between the two zinc plates of one element and the platinum of the next. This connecting wire takes a form somewhat resembling that of an S, being first soldered along the top of one zinc plate; then after a semicircular bend brought along the top of the other zinc plate of the same element and soldered to it, and finally, by a second semicircular bend, brought along the top of the platinum of the next element and soldered to it. The same mode of connexion was of course repeated throughout the battery, with the exception of trifling and obvious modifications at the end of each trough of cells. The soldered joints were varnished; each of those which attach the platinum plates was further protected from spatters and fumes by a piece of loose gutta-percha tubing, which was slipped lengthways over the wire after its under side had been slit for the platinum foil to pass through.

The S-shape of the connecting wires admits of any set of metals being at any moment withdrawn or introduced without disturbing the others.

The zincs not being folded at the bottom may be amalgamated by dipping them, first into acidulated water, then into a spare outer cell filled with mercury, and finally into their place in the battery. The excess of mercury drains off, and will be found after the battery has been taken asunder.

In dismounting the battery, the whole series of metals in each trough was withdrawn together by a frame, the essential parts of which are two parallel bars of wood, the interval between which can be adjusted, and which are somewhat longer than the trough. These bars are first to be separated sufficiently to enable the frame to be passed down over the S-connecting wires of the metals. The interval between the bars is then to be reduced, so that on raising the frame all the metals are carried with it, being supported by the projecting semicircular bends of the connecting wires resting on the bars of the frame. Frame and all are to be immediately dipped into a tank of water, and the frame with its metals then laid aside to drain till the battery is again required.

The workmanship of this form of battery is throughout of the simplest description*.

On Mr. Whitehouse's *Relay and Induction Coils in action on Short Circuit.* *By* Professor W. Thomson, *LL.D., F.R.S.*

The peculiarities of Mr. Whitehouse's induction coils, which fit them remarkably for the purpose for which they are adapted, as distinguished from the induction coils by which such brilliant effects of high intensity are obtained, were described. The chief part of the telegraphic receiving apparatus, the relay, was fully described, and was shown in action, through thirty yards of the Atlantic cable, after some remarks explaining the general nature of a relay,—an electrical hair-trigger. The relation of Mr. Whitehouse's relay to the Henley receiving instrument, was pointed out. The author expressed his conviction, that by using Mr. Whitehouse's system of taking advantage of each motion for a single signal, instead of the to-and-fro motion, as in all systems hitherto practised, the Henley single needle instrument might be easily used, so as to give as great a speed on one line of wire alone, as is at present attained by two with the double needle instrument. The beautiful method of reading by bells would be most ready and convenient for giving the indications to be interpreted as the messages, but the author believes that either by the eye or ear, messages may be read off with the rapidity and ease which will render the use of one telegraph wire in all respects as satisfactory as that of two.

On the Effects of Induction in long Submarine Lines of Telegraph. *By* Professsor W. Thomson, *LL.D., F.R.S.*

A general explanation of the theory was given, and the "law of squares" was proved to be rigorously true. It was pointed out, that when the resistances of the instruments employed to generate and to receive the electric current are considerable in comparison with the resistance of the line, the observed phenomena do not fulfil the law of squares, because the conditions on which that law is founded are deviated from. The application of the theory to the alternate "positive" and "negative" electrical actions used by Mr. Whitehouse for telegraphing was explained, and the circumstances which practically limit the speed of working were pointed out. Curves illustrating the enfeeblement of the current towards the remote end of the telegraph line, and the consequent necessity of the high pressure system introduced by Mr. Whitehouse, were shown. The embarrassment occasioned by the great electrical effect through the wire, which follows the commencement of a series of uniform signals with a full strength of electrical force, was illustrated in one diagram, which showed a succession of eight impulses following one another at equal intervals of time, and giving only one turn of the electrical tide at the remote end, or two motions of the relay, including the initial effect. The remedy suggested by

* For many purposes to which a battery may be applied, it is convenient to be able to form a connexion directly with any required cell. In the battery exhibited to the Association, this was simply provided for by one end of each S-wire being allowed to project and turned up for a binding-screw to be soldered to it.

the author was illustrated by another diagram, in which a succession of seven equal alternate applications of positive and negative force following a first impulse of half strength, was shown to give seven turns of the tide at the remote end, and therefore eight motions of the relay, following one another at not very unequal intervals of time.

Outline of a Theory of the Structure and Magnetic Phenomena of the Globe. By J. DRUMMOND.

The author, from the admitted fact of our earth having cooled down from an original state of fluidity, and that it now is a solid crust enclosing a fluid mass of molten materials, held that there must be an action of the sun and moon on this fluid mass analogous to that which caused the tides of the ocean; that from thence an outward pressure on the crust must result, propagated along it, in a manner similar to the great tidal wave; and from this principle, in an elaborate essay, he deduced the ordinary magnetic phenomena, as well as volcanoes, earthquakes, and other violent actions; concluding by answering objections which may be urged against the foundation and details of this theory.

Magnetic Experiments made on board the 'Great Eastern' Steamer. By W. RUNDELL. (*Communicated by* Admiral FITZROY.)

Admiral FitzRoy exhibited to the Section, and explained tables and a diagram, showing the deviations observed in a compass placed successively at each of eight stations along the deck of the monster iron vessel now building at Millwall.

SOUND.

On a singular Acoustic Phenomenon. By M. DONOVAN, *M.R.I.A.*

The author explained the beats which are experienced when two strings tuned nearly, but not exactly, to unison, are struck at the same time. He then stated that Earl Stanhope had observed these beats in all the tuning-forks tried by him, which he attributed to inequality of the prongs. Earl Stanhope, in consequence, had been at the pains to invent a new tuning instrument. This effect the author often tried to experience, but never could succeed until upon one occasion, just after he had ceased from violent exercise, having applied the fork to his teeth, he distinctly heard the beats. He was thus led to the true origin of the phenomenon, which he could now experience whenever he wished, by running a short distance, particularly up and down stairs. The effect was caused by the beatings of his own heart, which are synchronous with those of the fork.

On the Effect of Wind on the Intensity of Sound. By Professor G. G. STOKES, *M.A., D.C.L., Sec. R.S.*

The remarkable diminution in the intensity of sound, which is produced when a strong wind blows in a direction from the observer towards the source of sound, is familiar to everybody, but has not hitherto been explained, so far as the author is aware. At first sight we might be disposed to attribute it merely to the increase in the radius of the sound-wave which reaches the observer. The whole mass of air being supposed to be carried uniformly along, the time which the sound would take to reach the observer, and consequently the radius of the sound-wave, would be increased by the wind in the ratio of the velocity of sound to the sum of the velocities of sound and of the wind, and the intensity would be diminished in the inverse duplicate ratio. But the effect is much too great to be attributable to this cause. It would be a strong wind, whose velocity was a twenty-fourth part of that of sound; yet even in this case the intensity would be diminished by only about a

twelfth part. The first volume of the 'Annales de Chimie' (1816) contains a paper by M. Delaroche, giving the results of some experiments made on this subject. It appeared from the experiments,—first, that at small distances the wind has hardly any perceptible effect, the sound being propagated almost equally well in a direction contrary to the wind and in the direction of the wind; secondly, that the disparity between the intensity of the sound propagated in these two directions becomes proportionally greater and greater as the distance increases; thirdly, that sound is propagated rather better in a direction perpendicular to the wind than even in the direction of the wind. The explanation offered by the author of the present communication is as follows. If we imagine the whole mass of air in the neighbourhood of the source of disturbance divided into horizontal strata, these strata do not all move with the same velocity. The lower strata are retarded by friction against the earth, and by the various obstacles they meet with; the upper by friction against the lower, and so on. Hence the velocity increases from the ground upwards, conformably with observation. This difference of velocity disturbs the spherical form of the sound-wave, tending to make it somewhat of the form of an ellipsoid, the section of which by a vertical diametral plane parallel to the direction of the wind is an ellipse meeting the ground at an obtuse angle on the side towards which the wind is blowing, and an acute angle on the opposite side. Now, sound tends to propagate itself in a direction perpendicular to the sound-wave; and if a portion of the wave is intercepted by an obstacle of large size, the space behind is left in a sort of sound-shadow, and the only sound there heard is what diverges from the general wave after passing the obstacle. Hence, near the earth, in a direction contrary to the wind, the sound continually tends to be propagated upwards, and consequently there is a continual tendency for an observer in that direction to be left in a sort of sound-shadow. Hence, at a sufficient distance, the sound ought to be very much enfeebled; but near the source of disturbance this cause has not yet had time to operate, and therefore the wind produces no sensible effect, except what arises from the augmentation in the radius of the sound-wave, and this is too small to be perceptible. In the contrary direction, that is, in the direction towards which the wind is blowing, the sound tends to propagate itself downwards, and to be reflected from the surface of the earth; and both the direct and reflected waves contribute to the effect perceived. The two waves assist each other so much the better, as the angle between them is less, and this angle vanishes in a direction perpendicular to the wind. Hence, in the latter direction the sound ought to be propagated a little better than even in the direction of the wind, which agrees with the experiments of M. Delaroche. Thus the effect is referred to two known causes,—the increased velocity of the air in ascending, and the diffraction of sound.

Astronomy.

On the Distribution of the Orbits of the Comets in Space. By Cavaliere O. F. Mosotti.

The author not being present, this communication was read and explained by Prof. Bolzani. The author commenced by explaining that the simplest and most direct method of analysing the distribution of the comets in space would seem to be, to divide the celestial sphere by means of so many circles parallel to the ecliptic into equal zones corresponding to an aliquot part of the entire superficies, and then to ascertain how many culminating points are contained in each of these. If the orbits were uniformly distributed throughout space, each of them should contain about an equal number of these points; if not, the greater or less number contained in each will serve to show the tendency the orbits have to approach to or recede from that distribution. The author applied this method arithmetically in the first instance; and afterwards, in order to render the results more palpable, reduced them to a graphic construction. The learned Professor then exhibited and explained to the Section, in detail, the several formulæ on which the numerical examination of the question was founded, and then exhibited and explained the graphic construction

reduced to a planisphere. The same planisphere, when properly projected, was made to serve for both the northern and southern hemispheres, by colouring the projecting lines which marked radially on the outer circle the longitudes of the culminating points and of the perihelia for the northern hemisphere blue, and for the southern black; and on each of these radial lines was marked the number assigned to the comet in the catalogue of the 263 discussed by the author. If, then, we conceive these two lines to be produced to the centre, and caused to revolve towards the northern hemisphere if marked with the sign plus, to the southern if marked minus, until they take the position of the inclination of the orbit marked as belonging to each, the position of the two lines will present to the mind a picture of the position which the orbit will hold as well in space as in its own plane. At the end of each of the eight tables, corresponding to the eight zones, were specified the total number of orbits found in that zone, as well as the number of those having their perihelia in the northern or southern hemisphere, and their motion direct or retrograde; combining the data thence given, the author drew up the summary of the whole. He found the orbits to have a tendency to approach in prevailing numbers the polar regions of the ecliptic. The minimum occurs in the fifth zone of each hemisphere. Those whose perihelia are in the northern hemisphere exceed those whose perihelia are in the southern in the proportion of 3 to 2; the number of those having a direct motion to those retrograde as 5 to 6, or nearly equal. The author calls the Great Circle, which passes so as to divide the Milky Way pretty equally, the Galaxy Circle. In the centre of this the sun and earth may be considered to be placed; it cuts the ecliptic towards the solstitial points, and is inclined to it at about 60°. He then finds that the planes of the orbits of the comets are, for the most part, little, if at all, inclined to the plane of the Galaxy Circle, and that they go on decreasing in number as that inclination increases; and therefore he concludes that some cosmical cause must have led to such a result. Also, the perihelia of by far the greater number of those he has discussed are found near the Galaxy Circle, showing that when they are passing most closely under the influence of the sun they are both near the Galaxy Circle, and their proper motion is nearly parallel to its plane. Hence the greater number of comets come to us from the region of the Galaxy itself.

On a Moveable Horizontal Sun-dial, which shows correct Solar Time within a Fraction of a Minute. By M. DONOVAN, *M.R.I.A.*

The author first pointed out the inaccuracies incidental to or inseparable from the ordinary horizontal sun-dial, even when executed with the greatest care. He then adverted to the peculiarities of his own dial, showing how it can be placed with the greatest precision in the meridian of the place. After alluding to the defects of the ordinary style, he showed the advantages of substituting a human hair, which, casting a shadow as slender as itself for several inches of its length, affords a line of direction for another hair springing from the same source, which, when stretched through the centre of the most slender part of the shadow, marks the precise time to a few seconds on a large divided circle. One of the peculiarities of this dial is, that it may be placed in any spot illuminated by the sun; an advantage, from which the common horizontal dial is precluded by its being a fixture, and without means of exactly placing its meridian in the meridian of the place.

Tables to simplify and render more general the Method of finding the Time, by observing Circumpolar Stars in the same Vertical. By C. THOMSON. *(Communicated by* Sir W. R. HAMILTON.)

The author described the tables, and exhibited to the Section a little apparatus constructed by his ingenious assistant, Mr. Thomson, which illustrated the method of observing circumpolar stars for this purpose.

On the Direction of Gravity at the Earth's Surface. By Professor HENNESSY, *M.R.I.A.*

If the earth's surface be considered to coincide with that of the liquid which

covers three-fourths of the entire spheroid, gravity would be perpendicular to it at every point. If, however, the earth were stripped of all its seas and oceans, the surface would present considerable inequalities. From what is now known regarding the depth of the ocean, the continents would appear as plateaus elevated above the oceanic depressions to an amount which, although small compared to the earth's radius, would be considerable when compared to its outswelling at the equator, and its flattening towards the poles. The surface thus presented would be the true surface of the earth, and would not be perpendicular to gravity. If a mean surface be conceived intersecting this, so as to leave equal volumes above of elevations, and of depressions below it, it is not allowable to assume that such a surface is perpendicular to gravity. The mean surface of the solid crust of the earth would not be perpendicular to gravity, if, after the process of solidification had commenced, any extensive changes in the distribution of matter in the earth's interior could take place. If the fluid matter in solidifying underwent no change of volume, the forms of the strata of equal density within the earth would be the same as those of the primitive fluid mass, and would continue to be the same at every stage of its solidification. But if, as observation indicates, such fused matter, on passing to the solid crystalline state, should diminish in volume, the pressure on the remaining strata of the fluid would be relieved, and they would tend to assume a greater ellipticity than they had when existing under a greater pressure. The general result of this action would manifestly be to produce a change in the direction of the attractive forces at the outer surface of the solid crust. The direction of a plumb-line would be altered so as to slightly increase the apparent latitudes of places over a zone intermediate between the equator and poles.

On the Solidification of Fluids by Pressure. By Professor HENNESSY, *M.R.I.A.*

The views put forward were deduced from some propositions in the dynamical theory of heat contained in the writings of Prof. W. Thomson and Prof. Clausius. The general result arrived at regarding the influence of pressure on a fluid so circumstanced as to lose no part of the heat acquired by condensation, would be, that so long as the matter continued in a fluid condition, the resistance to compression from this cause would be very small. If, however, the fluid were on the point of changing its state to that of solidity, the effect of the latent heat of fusion, which by hypothesis could not be emitted, would interpose a resistance of great magnitude compared to that resulting from simple compression. The fused matter of which the interior of the earth most probably consists, would be under conditions similar to those mentioned, from the slow conducting power of the materials composing the earth, and from the pressure of all the outermost strata of equilibrium of the fluid upon those near the centre; and thus the influence of pressure in promoting solidification would be less than at its surface.

On the relative Accuracy of the different Methods of determining Geographical Longitude. By Professor LOOMIS.

The author first gave a rapid sketch of the several methods of determining differences of longitude adopted by astronomers and geographers, and pointed out the degree of accuracy that might be expected from each; and drew, as the conclusion of this branch of his subject, the importance of obtaining a method far more accurate than any of the preceding, and in which the personal equations of the observers would either be eliminated or greatly reduced; and such a desideratum he considered was afforded by the electric telegraph. He then explained at length the various methods resorted to by Dr. Bache, Prof. Morse, himself, and other American philosophers, the chief peculiarity of which was using either a sidereal and mean-time clock at the recording-station; the beats of these, coinciding every six minutes, gave well-marked equidistant points of time to which to refer the signals received every second from the observing end or station; or by using a sidereal clock and chronometer, beating twice each second, intervals of three minutes became similarly marked out. Then, by alternating the stations at which the observations were made and

recorded by interchanging the observers at these stations, the nstruments remaining unchanged, and by various mechanical improvements in the recording apparatus of the telegraph, chiefly with a view to ensure uniformity of motion in the slips on which the recording dots were impressed, he showed that a degree of accuracy hitherto not approached by any other method had been obtained,—the error of both clocks disappearing also in the results, if only their rates had been made perfect.

On a Proposal for the Establishment of a Uniform Reckoning of Time in connexion with the Telegraph. By J. J. Murphy.

The author said, that as in Britain the establishment of the telegraph had made it necessary to adopt Greenwich time all over the country, where the difference was small this was possible, but when the telegraph extended to America, or greater distances, it would cease to be so. He proposed that all clocks should be furnished with a double circle of figures on the dial, the outer circle being moveable through any required number of degrees. When a clock is set up at any place, let the hands show local time on the inner circle; and let the outer circle be so set, that the hour-hand will on it show Greenwich time.

On some Phenomena in connexion with Molten Substances. By J. Nasmyth, *F.R.A.S.*

The author stated, on introducing the above subject to the notice of the Section, that his object in so doing was to direct the attention of scientific men to a class of phenomena, which although in their main features they might be familiar to practical men, yet appeared to have escaped the attention of those who were more engaged in scientific research. The great fact which he desired to call attention to is comprised in the following general proposition, namely, that all substances in a molten condition are specifically heavier than the same substance in an unmolten state. Hitherto water has been supposed to be a singular and special exception to the ordinary law, namely, that as substances were elevated in temperature they became specifically lighter, that is to say, water at temperature 32° on being heated does on its progress towards temperature 40° become more dense and specifically heavier until it reaches 40°, after which, if we continue to elevate the temperature, its density progressively decreases. From the facts which Mr. Nasmyth brought forward, it appears that water is not a special and singular exception in this respect, but that, on the contrary, the phenomenon in relation to change of density (when near the point of solidification) is shared with every substance with which we are at all familiar in a molten state, so entirely so, that Mr. Nasmyth felt himself warranted in propounding, as a general law, the one before stated, namely, that in every instance in which he has tested its existence, he finds that a molten substance is more dense, or specifically heavier, than the same substance in its unmolten state. It is on account of this, that if we throw a piece of solid lead into a pot of melted lead, the solid, or unmolten metal, will float in the fluid, or molten metal. Mr. Nasmyth stated, that he found that this fact of the floating of the unmolten substance in the molten, holds true with every substance on which he has tested the existence of the phenomenon in question; as, for instance, in the case of lead, silver, copper, iron, zinc, tin, antimony, bismuth, glass, pitch, rosin, wax, tallow, &c.; and that the same is the case with respect to alloys of metals and mixtures of any of the above-named substances: also, that the normal condition as to density is resumed in most substances a little on the molten side of solidification, and in a few cases the resumption of the normal condition occurs during the act of solidification. He also stated, that, from experiments which he had made, he had reason to believe that by heating molten metals up to a temperature far beyond their melting-point, the point of maximum density was, as in the case of water, at 40° about to be passed; and that at such very elevated temperatures, the normal state, as regards reduction of density by increase of temperature, was also resumed, but that as yet he has not been able to test this point with such certainty as to warrant him to allude further to its existence.

Mr. Nasmyth concluded his observations by stating, that he considered this to be a subject well-worthy of the attention of geologists, who might find in it a key to

the explanation of many eruptive or upheaving phenomena, which the earth's crust, and especially that of the moon, present, namely, that on the approach to the point of solidification molten mineral substances then beneath the solid crust of the earth must, in accordance with the above-stated law, expand, and tend to elevate or burst up the solid crust,—and also express upwards, through the so cracked surface, streams more or less fluid of those mineral substances which we know must have been originally in a molten condition. Mr. Nasmyth stated, that the aspect of the lunar surface, as revealed to us by powerful telescopes, appeared to him to yield most striking confirmation of the above remark. He concluded by expressing a hope, that the facts which he had brought forward might receive the careful attention of scientific men, which their important bearing on the phenomena in question appeared to him to entitle them to.

On certain Planetary Perturbations. By the Rev. W. G. Penny.

It appears that there are in the motions of several of the planets inequalities arising from the product of the disturbing forces of two planets, which inequalities appear to have been but little noticed hitherto, but which seem to be much larger than might have been expected, owing to the length of time during which they are accumulating. The most remarkable is one which exists in the motions of Mars and the earth. Its period is about 1800 years, or about twice that of the long inequality of Jupiter and Saturn. In the case of the earth it appears to amount to about $7\frac{1}{4}''$, and is owing to the product of the disturbing forces of Jupiter and Mars; and in the case of Mars it seems to amount to about $45\frac{1}{2}''$, and is owing to the product of the disturbing forces of Jupiter and the Earth. It arises from the fact, that four times the mean motion of the earth is very nearly equal to eight times that of Mars *minus* three times that of Jupiter. Its value for the earth is represented by the following equation:—

$$\delta\theta_2 = 7''\cdot293 \sin(8n_3t - 4n_2t - 3n_4t + 8\epsilon_3 - 4\epsilon_2 - 3\epsilon_4 + 75^\circ\ 14');$$

and for Mars by the equation

$$\delta\theta_3 = -45''\cdot684 \sin(8n_3t - 4n_2t - 3n_4t + 8\epsilon_3 - 4\epsilon_2 - 3\epsilon_4 + 73^\circ\ 34');$$

where n_2, n_3, n_4 are the mean motions of the earth, Mars, and Jupiter. This inequality is remarkable as being, if the work is correct, larger, and in the case of Mars very considerably so, than any which arise from the simple perturbation of a single planet,—the largest hitherto known in the case of the earth amounting to only $7''\cdot15$, and in the case of Mars to $25''\cdot5$. Also, there will be a corresponding inequality in the motion of the moon, which I have not yet examined, but which may, perhaps, be sensible; for, according to the investigations of M. Hansen, the inequality in the motion of the earth discovered by Prof. Airy, amounting to $2''\cdot04$, with a period of 240 years, produces one of not less than $23''$ in the motion of the moon, so that, judging by analogy, there ought to be a sensible inequality in the present case also. Again, there seems to be an inequality in the motions of Jupiter, Saturn, and Uranus, with a period of somewhat more than 1700 years, and amounting in the case of Jupiter to about $10''$; and in the case of Saturn to about $40''$; and in that of Uranus to $43''$. It arises from the fact, that six times the mean motion of Saturn is nearly equal to twice that of Jupiter *plus* three times that of Uranus. There are several others besides these of less importance, arising from the product of two disturbing forces; and there is even one which results from the product of three forces, and appears to amount to nearly $7''$. There are also several inequalities of the same kind in some of the asteroids, which are very much larger than any in the motions of the principal planets; but as the theory of the asteroids is considered to be of comparatively little interest, I have not sent them.

On Transit Observations of the Moon. By the Rev. T. R. Robinson, *D.D.*

Dr. Loomis's remarks on longitudes, deduced from the method of moon culminating stars, reminded him of the results which he had formerly obtained by it. The high praise given to it by the German astronomers, and his valued friend the late Mr. Baily, had induced him to attend to it particularly when determining the longitude of the Armagh Observatory. He found it very unsatisfactory. The longitudes, deduced by comparison *on the same night* with Dublin, Greenwich, Paris, and Königsberg, all first-rate Observatories, were very discordant; and those deduced

from the first limb by himself, and the second by his assistant, once differed 50″. He found the cause of this to be, that the personal equation of the observers differs, and unequally, for the two limbs, and both are greater than for stars. The reason of this is obvious, for the field round the moon is very dark by contrast, and it is not easy to compare a luminous space with a dark one. He found that in fog, when the field is nearly as bright as the lunar disc, the longitudes were the most consistent, and this led to a mode of illumination which proved effective, and which he now mentioned in hope that it might be useful to travellers, as a most effective means of getting longitude, if provided with a transit, especially one similar to the "Broken telescope" of Reichenbach's universal instrument. He placed in front of the object-glass a disk of emerald glass, from the centre of which a circle is cut, four-tenths of the diameter of the object-glass. This portion forms the image, but the remaining portion fills the field with scattered light from the moon, while it contributes none to the image. The effect is similar to that of the fog, and it nearly reduces the personal error to that of stars. The small aperture, however, gives a larger diameter of the moon, and therefore both limbs should be used in nearly equal proportion. With these precautions he thought the longitude could be obtained more certainly than by any other means within the reach of a traveller, certainly far surpassing the ordinary one of lunar distances.

On Lunar Physics,

In a Letter from Professor P. Smyth *to the* Assistant General Secretary.

Royal Observatory, Edinburgh,
27th August, 1857.

Dear Sir,—I have to report one more step in the delineation of the moon, according to the plan recommended by the British Association, viz. the engraving of three views of the Mare Crisium; and I have sent to you, per railway, a parcel containing several copies, of which I will request you to lay one before the British Association, and to present the others to the officers, as thus:—Rev. Dr. Lloyd, *President*; Sir W. R. Hamilton, *late President*; Rev. Dr. Robinson, *late President*; General Sabine, *Secretary*; Prof. Phillips, *Assistant Secretary*. You will find by what I have said on page vi of the pamphlet, that I only look on the present engravings as a first instalment towards putting our knowledge of this part of the moon on a satisfactory footing.

Yours very truly,
C. Piazzi Smyth.

Meteorology.

Notice of Meteorological Observations made at Sea. Communicated by Rear-Admiral FitzRoy, *F.R.S.*

Admiral FitzRoy drew the attention of the Section to the meteorological papers lying on the table, which had been recently published by the Board of Trade. The Report to which he referred would show what progress had been made, and therefore he would not occupy valuable time by entering into verbal details. He would only observe generally, that a great number of valuable observations had already been made on board some hundred ships, with excellent instruments approved by the Kew Committee of the British Association, and that those observations were regularly tabulated in such a manner as to admit of their being combined in groups or used individually. The willing cooperation of officers at sea had already accumulated more observations than can be reduced and tabulated with corresponding quickness; therefore more reduction of observations, rather than more observers with a larger number of instruments, seems necessary; and this can only be accomplished by employing a larger staff. The Government had shown the utmost willingness to attend to the recommendations of competent authorities with respect to the establishment and support of the Meteorological Office at the Board of Trade; and only desired to apply the vote sanctioned by Parliament for meteorological observations at sea to the best possible advantage. The United States, Great Britain, and Holland, had already cooperated largely in this work; and France had lately established a similar department for collecting and discussing such observations.

On the Variation in the Quantity of Rain due to the Moon's Position in reference to the Plane of the Earth's Orbit. By C. FULBROOK.

The author called attention to an important difference in the amount of rain which falls in these latitudes at opposite parts of the moon's course with reference to the plane of the earth's orbit:—a result obtained by placing horizontally (from the daily register of Howard, in the vicinity of London) the amount of rain (when any) due to each day throughout a lunar course, and so on for 100 courses in due order. The following Table exhibits the result:—

Position of the Moon with reference to the Plane of the Earth's Orbit in its connexion with the Rain-fall of London and its vicinity, as deduced from a Register of the Weather during 100 courses of that Luminary.

Position of the Moon.	Days.	Amount of Rain.
In greatest South Latitude.	1	
	2	
	3	47·60 inches in 500 days.
	4	
	5	
	6	
Ascending through the plane of earth's orbit.	7	
	8	
	9	
	10	
	11	
	12	
	13	
	14	
	15	
	16	
	17	26·42 inches in 500 days.
In North Latitude.	18	
Descending through the plane of earth's orbit.	19	
	20	
	21	
	22	
	23	
	24	
In South Latitude.	25	
	26	
	27	

This effect the author supposes to be due to alternate southerly and northerly currents depending on the ascent and descent of the moon through the plane of the earth's orbit. Be this as it may, it is reasonable to infer, that when she is thus in some way producing an excess of rain in these latitudes, comparatively dry weather obtains in corresponding southern latitudes, and *vice versâ*; and that intermediate latitudes experience an intermediate degree of the effect. Meteorologists of other latitudes and distant countries, who may possess a register of the weather extending over one hundred courses, or about seven years and a half, should try the result for their respective latitudes, and transmit their conclusions to the author.

On Simultaneous Isothermal Lines. By Professor HENNESSY, *M.R.I.A.*

Having briefly referred to the interest shown by the Association in the question of distribution of temperature over the surface of the earth by the publication of the maps of Prof. Dove, and acknowledged the importance of the results furnished by a comparison of mean temperatures in connexion with the climatology of the globe, Mr. Hennessy proceeded to describe the new species of isothermals now proposed.

If temperature were recorded at every station on the surface of the earth at the mean time corresponding to any given meridian, then a line traversing the places where such temperatures were found to be equal would be a simultaneous isothermal line. The forms of such lines would manifestly depend on the diurnal range of temperature at the several stations, as well as the several physical conditions influencing mean temperature. If the earth were absolutely at rest, and stripped of its fluid coverings, these lines would be circles, having their planes perpendicular to a line joining the centres of the earth and sun. This would be nearly the case in a body turning very slowly on its axis, like our satellite, in which Prof. Hennessy anticipated that observations would ultimately show a great diminution of heat radiated from the edges compared to the centre of the illuminated disk. With a more rapid motion of rotation, as in the case of the earth, the isothermals would be elongated in a direction parallel to that of the rotation. On introducing the influence of all the actual motions of the earth, and of the emissive and absorbing powers of the atmosphere, the ground, and the sea, the forms of these lines would be considerably modified. The forms of the isothermals on the land and sea would necessarily differ, and might be expected to present some important relations to the directions of land and sea breezes. It appears, in general, far more probable that a knowledge of the contemporaneous conditions of temperature at different places would assist in pointing to a connexion between these phenomena and atmospheric perturbations rather than a knowledge of mean temperature. Atmospheric currents, whether vertical or parallel to the earth's surface, depend upon contemporaneous differences of temperature. A similar remark might be applied to many other important atmospheric phenomena, and these lines would also serve to indicate more clearly, or to lessen the possibility of the supposed connexion between terrestrial magnetism and terrestrial temperature.

On the Distribution of Heat over the Surface of the British Isles. *By* Professor HENNESSY, *M.R.I.A.*

Since the author had communicated to the Section at the Cheltenham Meeting of the Association an account of his general views as to the laws of distribution of isothermal lines, further confirmation of these views had arisen. It had been already shown that the isothermals in Ireland are partly closed curves surrounding a space of minimum temperature, having its centre a little to the north-east of the centre of the island. With the aid of the observations collected and published by Mr. Glaisher, those contained in Prof. Dove's Reports, and a few additional isolated results, the isothermals for Great Britain have been laid down on the map exhibited to the Section. No correction has been made for elevation above the sea-level, as atmospherical phenomena do not depend upon the fictitious temperatures so deduced, but upon their actual amounts. This non-reduction would partly account for the remarkable decrease in temperature in going from the coast towards the interior of the island, and by which the space of minimum temperature in Great Britain appears to occupy a position between the midland counties of England and the north of Scotland, where it expands to its greatest breadth. The influence of distance from the sea and of height above it are, doubtless, both combined in producing the remarkable forms of the isothermals of the British Isles, and it would therefore be desirable in future tables of the distribution of temperature to have the former element noted in connexion with each station as well as the latter.

On the Vertical Currents of the Atmosphere. *By* Professor HENNESSY, *M.R.I.A.*

The anemoscope described by the author at the Cheltenham Meeting of the Association having been since modified, has enabled him not only to observe the vertical direction of atmospheric currents, but also to compare the intensity of the vertical with the horizontal force of such currents. This is done by observing the angle of inclination of a moveable flange, which is turned by the vertical and horizontal components of the current until it is in equilibrium. By integrating the elements these components at each side of the flange, it was easily shown that the horizontal force, multiplied by the tangent of the angle of inclination, would give the vertical

force of the wind, and that the absolute force would be found by multiplying the horizontal force by the secant of the inclination. The vertical anemoscope might thus be usefully combined with one of the horizontal anemometers now in use in meteorological observatories. Among the general results of Prof. Hennessy's observations, it appears that the wind rarely blows in a perfectly horizontal direction. The deviations from that direction, although usually very small, are sometimes very remarkable, and follow each other in such a way, especially during strong breezes, as to indicate a species of undulatory motion in the wind. The force of the wind given by horizontal anemometers is thus almost always a little inferior to its actual mechanical energy. True vertical currents are sometimes indicated by the anemoscope when the flange points continuously and steadily in an upward or downward direction. This is usually observed when the air is otherwise in a comparatively calm state. The vertical ascending currents, which have been long supposed to take place over the land during fine weather, in connexion with the phenomena of sea and land breezes, were often very distinctly observed. The obvious connexion of vertical currents with changes of temperature and other atmospheric disturbances, points to the importance of observing them, as well as the horizontal movements of the air.

On the Discovery of the Asteroid, No. 46, *on the* 17*th of August*, 1857, *by* Mr. Pogson, *at Oxford. By* Dr. Lee, *F.R.S.*

Dr. Lee said, on the morning of the 17th of August, being in Oxford, I received from Mr. Pogson the following statement :—" I have the pleasure of sending you the reduced observations of a new planet, either Daphne, or the forty-sixth Asteroid, most probably the latter, which I found last night with your beautiful Smythian telescope. Mr. Frodsham's chronometer and Mr. Dollond's ring-micrometer have done me good and unexpected service, and we are now tried trusty friends. The following were my observations, which have taken nearly all night to reduce :—

Oxford Mean Time.	Apparent R. A.	South Declin.
h m s	h m s	° ′ ″
August 16, 9 49 10	20 20 27·16	16 20 53·7
„ „ 10 47 24	20 20 25·61	16 21 2·0
„ „ 12 29 51	20 20 22·69	16 21 18·4

Daily motion 39″ retrograde, 3′ 34″ south, magnitude $11\frac{1}{4}$, observations duly corrected." This discovery was made under considerable difficulties and discomforts; but the zeal and intelligence and the practised eye of the observer were able to overcome them. Mr. Pogson has been for some time engaged at his leisure hours, and after his public duties at the noble Radcliffe Observatory were terminated, in making maps of stars in the region near the ecliptic, and by a course of systematic investigation he discovered, in 1856, the planet Isis (No. 42) by these means, with the equatoreal in the Radcliffe Observatory, which fact is mentioned in the Report of the Council of the Royal Astronomical Society for the year 1856, during the presidency of the distinguished astronomer, Mr. M. Johnson, F.R.S., the director of that observatory. This present planet, No. 46, was discovered by him with the aid of a similar star-map, but not in the Radcliffe Observatory, with all the conveniences and appliances which are to be found in such an establishment,—but at his private residence, and in a small garden, not larger than this room, and in the open air, and with the aid of a common lamp,—but with the assistance of Mrs. Pogson, who wrote down the chronometer times as he called them out, in order that his eye might not be troubled with turning from the eye-piece of his telescope to a paper. On the evening of the 16th of August, whilst sweeping for variable stars, a stranger appeared in the telescope which was not in Mr. Pogson's map of stars, and it was therefore strictly examined, and this led to its detection; and the evening being most favourable for observation, after a series of three courses of observations, it was found to be a planet. It was situated between β and π Capricorni, in hour 20. Mr. Pogson describes the object-glass of his telescope with great admiration; and the ring-micrometer, which was made expressly for it by Mr. Dollond, and the chronometer, which has been lent to him by the liberality of Mr. Frodsham, as being excellent; and it is worthy of remark, that the object-glass of the Smythian refractor, which was made for

Admiral Smyth by Tulley, is only $3\frac{3}{4}$ inches, and the object-glass of the Radcliffe equatoreal is $7\frac{1}{4}$ inches. The planet was seen again in the evening of the 22nd of August with the Radcliffe equatoreal, but exceedingly faint; and on the evening of the 23rd, it was again seen with the Smythian refractor, and it appeared but a very little fainter with the latter than with the former; which fact may serve to put amateur astronomers on their guard in the purchase of object-glasses, and as evidence that the largest object-glasses are not necessarily the best.

On the Results of Measurements of γ *Virginis for the Epoch* 1857. *By* Rear-Admiral SMYTH, *D.C.L., F.R.S.* (*Communicated by* Dr. LEE, *F.R.S.*)

The fine double star γ Virginis, to which Admiral Smyth has for some years devoted much attention, is one of the most remarkable specimens of a binary system in the sidereal regions, the history of which is fully related both in his work 'The Celestial Cycle,' and the 'Ædes Hartwellianæ.' It has been very assiduously watched by the best astronomers of the age, and its motions so clearly ascertained, as to offer sufficient phenomena to induce a conviction that the Newtonian law of gravitation obtains in the remote stellar regions. Besides the Hartwell observations, the latest series of which are here presented, this epoch 1857 has been also watched by the Astronomer Royal, Mr. Airy; and by the Rev. W. R. Dawes, of Haddenham; and by Lord Wrottesley, at his well-conducted observatory, near Wolverhampton; and by Mr. Isaac Fletcher, of Tarn Bank, Workington. For a confirmation of the merits of Admiral Smyth, I might refer to Lord Wrottesley, to whom the public are indebted, not only for his attentions to the orbit of this star, but also for his important Catalogue of Stars, as well as for the services which he has rendered to this Association as President of the Royal Society.

On certain Electrical Phenomena in the United States. By Professor LOOMIS.

Atmospheric electricity is very abundant in the United States, and often exhibits phenomena more remarkable than are witnessed in most of the countries of Europe, especially in England and Germany. These phenomena are not confined to any particular season of the year; but the exhibitions in summer appear under a different form from those of winter. In summer, free electricity exhibits itself chiefly in the form of lightning during thunder-storms; and these exhibitions are often among the most sublime and impressive phenomena witnessed in any part of the globe. The telegraph wires are exceedingly sensitive to the approach of a thunder-storm. The wires are often charged with electricity, from the effects of a storm so distant that no thunder is heard or lightning seen. I have often stood at such times in a telegraph office, and introduced my own body into the electric circuit, by taking hold of a telegraph wire with one hand, and with the other hand grasping a wire which communicated with the earth. A frequent twinge is felt in the arms and sometimes through the breast. The shock is pungent and painful, even when scarcely the slightest spark can be obtained by bringing the two wires nearly in contact. Such experiments are unsafe when the electric cloud is near. If, during the passage of a thunder-shower, the telegraph apparatus is left in communication with the long telegraph wires, the fine wires of the electro-magnets are almost sure to be melted, and the magnets thereby rendered useless. Sometimes, in telegraphic offices, there occurs an explosion, which melts large wires and is dangerous to human life. The effect of a feeble current of atmospheric electricity on the telegraph wires is the same as of a current from a galvanic battery. It makes a dot on the telegraph register; and when a thunder-storm passes in the neighbourhood of a telegraph line, those dots are of constant occurrence; and being interposed between the dots of the telegraph operators, they render the writing confused and often illegible. The operators are therefore commonly compelled to abandon their work when a thunder-shower prevails in the vicinity of any part of the line.

The aurora borealis is very common in the United States, even in summer; but, on account of the long-continued twilight, it is seldom witnessed with such brilliancy in summer as in winter. During winter, thunder-storms in the United States are of very rare occurrence; but even at this season they are not entirely unknown. Some-

through the breast. The shock is pungent and painful, even when scarcely the slightest spark can be obtained by bringing the two wires nearly in contact. Such experiments are unsafe when the electric cloud is near. If, during the passage of a thunder-shower, the telegraph apparatus is left in communication with the long telegraph wires, the fine wires of the electro-magnets are almost sure to be melted, and the magnets thereby rendered useless. Sometimes, in telegraphic offices, there occurs an explosion, which melts large wires and is dangerous to human life. The effect of a feeble current of atmospheric electricity on the telegraph wires is the same as of a current from a galvanic battery. It makes a dot on the telegraph register; and when a thunder-storm passes in the neighbourhood of a telegraph line, those dots are of constant occurrence; and being interposed between the dots of the telegraph operators, they render the writing confused and often illegible. The operators are therefore commonly compelled to abandon their work when a thunder-shower prevails in the vicinity of any part of the line.

The aurora borealis is very common in the United States, even in summer; but, on account of the long-continued twilight, it is seldom witnessed with such brilliancy in summer as in winter. During winter, thunder-storms in the United States are of very rare occurrence; but even at this season they are not entirely unknown. Sometimes in mid-winter, after a series of unusually warm days, a strong wind suddenly springs up from the west, attended by a shower, during which several flashes of lightning, accompanied by thunder, are noticed. Such a shower is invariably followed by a great and sudden fall of the thermometer. But while electrical discharges in the form of lightning are rarely witnessed in winter, other electrical phenomena of great interest are of almost daily occurrence. Those phenomena consist of free electricity residing upon almost all bodies resting on the earth, but sufficiently insulated. This free electricity is particularly noticeable on the clothes and hair of the human body. During the cold months of winter, the human hair is commonly electrical, and especially when it is brushed with a fine comb. Often at such times the fine hairs are seen to stand erect; and the more you comb to make them smooth, the more obstinately they refuse to keep their proper place. If you present your fingers to those electrified hairs, they fly to meet you, like a lock of dry hair attached to the prime conductor of an electric machine. In such cases there is but one remedy; the hair must be thoroughly moistened, after which it lies quietly in its place. During the same season of the year, all woollen articles of clothing become highly charged with free electricity. The pantaloons in particular are found to attract light floating particles of dust, down, &c., especially near the feet; and it is impossible to cleanse them by brushing. The longer you brush, the more your clothes are covered with dust and lint. Nothing less than a wet sponge is efficient to cleanse them. At night, when you take off your pantaloons, you hear a distinct crackling noise, and in a dark room perceive a succession of flashes. You draw your fingers down over them, especially near the lower extremities, and you perceive a repetition of the crackling noise, accompanied by distinct flashes of light. As you take off your flannel drawers, the crackling is again heard, louder than before, and the flashes of light are more vivid. If you take a woollen blanket from your bed, hold it suspended in your left-hand, and draw the fingers of your right-hand over it, the crackling is equally loud and longer continued. Your fingers seem enveloped in a blaze of light, and the flashes can be several times renewed. Brute animals do not escape the general electrical influence. In a cold frosty night, you draw your hand gently over a cat's back, and you hear a distinct crackling noise, while the cat shows unmistakeable signs of bad temper, and refuses her consent to play the philosopher with you. Persons riding on horseback during a snow-storm in the night have frequently noticed the extremities of their horse's ears tipped with light, like that of a pale, steady flame. The preceding phenomena are either unknown in summer or are only noticed occasionally, and in an inferior degree; but the aurora borealis is often witnessed in the United States during winter, and frequently attains a splendour such as is surpassed in but few portions of the globe. During the severity of winter, and especially in houses which are furnished with heavy carpets and kept thoroughly warmed, even more remarkable electrical phenomena are often witnessed. If you walk across such a carpet with a slight shuffling motion, and then present your knuckle to some metallic object, as the knob of a door, you perceive a

decided spark and a faint snap. By walking rapidly two or three times back and forth, the spark may be increased, and becomes, perhaps, a quarter of an inch or more in length, and has great intensity accompanied by a smart snap. This phenomenon is not peculiar to any particular house or style of carpet, but in the cold months can be witnessed in almost every house in New York where there is a thick woollen carpet, and the room is kept habitually well-heated and dry. In some houses these phenomena are so remarkable that persons who have never witnessed them have listened to the accounts with evident incredulity.

A few winters ago I received from a female friend an account of some phenomena which she had witnessed at the house of Mrs. C. in New York, and which appeared so remarkable that I concluded the account must be greatly exaggerated. I was induced to call on Mrs. C., and request her to favour me with an exhibition of her electrical powers, to which request she readily acceded. We were sitting in a parlour covered with a heavy velvet carpet, and lighted with gas by a chandelier suspended from the ceiling. Mrs. C. rose from her chair, advanced one or two short steps, and gave a slight spring towards the chandelier, which was above her reach when her feet rested upon the floor. As her finger approached the metal I perceived a brilliant spark and heard a snap such as would have attracted the attention of a person casually walking through the hall, separated from the parlour by a closed door. The spark was more brilliant than that which is furnished by an ordinary electrophorus when most highly excited, but its length was not so great. A few steps upon the carpet were sufficient to renew the electric charge, and the spark was perceived whenever Mrs. C. touched a metallic object, like the knob of a door or the gilded frame of a mirror. The facts which had been before recited to me now no longer appeared incredible, and most of them I verified by my own observations. On approaching the speaking tube to give orders to the servants, Mrs. C. repeatedly received a very unpleasant shock in the mouth, and was very much annoyed by the electricity until she learned first to touch the tube with her finger. In passing from one parlour to the other, if she chanced to step upon the brass plate which served as a slide for the folding-doors, she received an unpleasant shock in the foot. A visitor upon entering the house, in attempting to shake hands with Mrs. C., received a shock which was quite noticeable and somewhat unpleasant. A lady on attempting to kiss her was saluted by a spark from her lips. Her little girl on taking hold of the knob of a door received so severe a shock that she ran off in great fright. Larger children frequently amused themselves by shuffling about on the carpet and giving each other sparks from their fingers. The preceding is the most remarkable case I have myself witnessed; but I have heard of several other houses in New York which appeared about equally electrical; and most of these phenomena have become so familiar in New York that they have ceased to excite surprise. The electricity thus developed exhibits the usual phenomena of attraction and repulsion, and is capable of igniting combustible bodies. By skipping a few times across the room with a shuffling motion, and then presenting the knuckle to an open gas-burner, the gas may be ignited. This experiment generally fails unless the burner be warm; but if after a jet has been some time burning you extinguish the flame and then draw a spark with your knuckle from the warm burner, the gas is readily ignited. After a careful examination of several cases of this kind, I have come to the conclusion that the electricity is excited by the friction of the shoes of the inmates upon the carpets of the house. I have found by direct experiment, that electricity is developed by the friction of leather upon woollen cloth. For this purpose I stood upon an insulating stool, and spreading a small piece of carpeting upon a table before me, rubbed a piece of leather vigorously upon it; and then bringing the leather near the cap of a gold-leaf electrometer, found that the leaves were repelled with great violence. The electricity of the leather was of the resinous kind. Electricity must therefore necessarily be excited whenever a person walks with a shuffling motion across a carpet; but it may be thought remarkable that the electricity should be intense enough to give a bright spark. In order to produce the highest effect, there must be a combination of several favourable circumstances. The carpet, or at least its upper surface, must be entirely of wool and of a close texture. From my own observations I infer that heavy velvet carpets answer this purpose best. Two thicknesses of ingrain carpeting answer very well. A drugget spread upon an ingrain car-

pet yields a good supply of electricity. The effect of the increased thickness is obviously to improve the insulation of the carpet. The carpet must be quite dry, and also the floor of the room, so that the fluid may not be conveyed away as soon as it is excited. These conditions will not generally exist except in winter, and in rooms which are habitually kept quite warm. The most remarkable cases which I have heard of in New York have been in close, well-built houses, kept very warm by furnaces. These furnaces are erected in the cellar and are filled with anthracite coal, which is kept constantly burning from autumn till spring. The heated air is conveyed to the hall, the parlours, and to every room in the house, as far as is desired, through large flues built in the walls, the flues having a section of about one square foot. In such a house the wood during winter becomes very dry, and all the furniture shrinks and cracks. The electricity is most abundant in very cold weather. In warm weather only feeble signs of electricity are obtained. The rubber, viz. the shoe, must also be dry like the carpet, and it must be rubbed upon the carpet somewhat vigorously. By skipping once or twice across a room with a shuffling motion of the feet a person becomes highly charged; and then upon bringing the knuckle near to any metallic body, particularly if it have good communication with the earth, a bright spark passes. In almost any room which is furnished with a thick woollen carpet, and is kept tolerably warm and dry, a spark may thus be obtained in winter; but in some rooms the insulation is so good, and the carpets are so electrical, that it is impossible to walk across the floor without exciting sufficient electricity to give a spark. It may be thought that in walking across a room there is but little friction between the shoe and carpet, but it should be remembered that the rubber is applied to the carpet with uncommon force, being aided by the entire weight of the body, so that a slight shuffling motion of the feet acts with great energy.

Account of an instance of Converging Rays seen at Greenisland, on the Antrim Shore of Belfast Lough, August 13, 1857. *By* J. J. MURPHY.

At about 6 P.M., after a thunder-storm—which was the second on that day—a rainbow was formed. The phenomenon to be described was seen about the left-hand part of the rainbow. The sky outside the rainbow was of that purple black which accompanies thunder-storms. Inside it was lighter, and diversified by alternate dark and bright rays, like those of an aurora, which appeared to converge to a point a little above the centre of the rainbow, but below the horizon. These rays fluctuated like those of an aurora, but much less rapidly, their changes being scarcely quick enough to be visible. The dark rays extended through the rainbow, almost blotting it out where they crossed it. The rays were continued outside the rainbow at the period of their greatest intensity, but not all the time, and were never so distinct outside as inside. The dark rays were of the same purple black colour as the sky outside the rainbow; the light rays were like what we call "watery sunshine." This appearance lasted in all about three-quarters of an hour. The light rays began to disappear one by one from the horizon upward,—the dark ones being welded together into a mass of purple darkness, which, as it ascended, blotted out the rainbow. In this way the lower part of the rainbow and the rays disappeared. The upper part of both disappeared by vanishing, the rays being the last completely to disappear. After this, there was some thunder and much rain. Another rainbow was formed during the evening which did not contain any rays, but resembled the former in having a dark sky outside and a light one inside.

Examination of some Problems of Meteorology. New and complete Explanation of the Rainbow. By M. L'ABBÉ RAILLARD.

The principal object which I present today, is a new and complete explanation of the rainbow. I show that the efficient rays of Descartes never enter into the formation of this phenomenon, but that it is always and solely produced by interferences. I apply to the rainbow the principle of interferences, not only as Dr. Young has done it, in his explanations of the supernumerary bows, but according to the much more exact and complete views of Mr. Airy. Dr. Young preserves in fact to the primary

bow, a constant radius, while according to that of Mr. Airy, it ought to be variable, a matter which entirely agrees with observations made. I have added to my memoir a drawing, which represents, according to these two theories, the variations which the rainbow's fringes of interference undergo according to the different diameters of the drops, from two millimetres to two hundredths of a millimetre, and for the two extreme colours of the solar spectrum, the red next the ray C, and the violet next the ray H.

The simply punctuated curves of this drawing give the deviation of the maxima and minima red and violet of different orders for a given diameter of the drops, the abscissæ of these curves representing the deviations of the different points of each fringe; and the ordinates, the proximate intensities of these points in the theory of Young. The curves with a full and coloured line represent the real action of the phenomenon; they only give the variations of the first two fringes, red as well as violet, the numerical results of Mr. Airy having only furnished me with means of cyphering a greater number. But these first two fringes are by far the most important, and are more than sufficient to fix the real theory of the rainbow, and of all the variations which it undergoes in its breadth, ray, and the shade of its colours; as also the theory of supernumerary bows, the white rainbow, the crowns opposite the sun, which are nothing else but supernumerary bows, as I demonstrate; and finally, to explain the absence of the coloured rainbow in fogs and rainless clouds. The relative intensities of the different points of these two fringes are not indicated in an arbitrary manner by the ordinates of the curves which represent them. I have determined them as faithfully as I could, making use of the drawings and numbers published by Mr. Airy in his learned "Memoir on the Intensity of Light in the vicinity of a Caustic."

The columns of figures contained in my Table give a facility in passing from one system to another, by means of a formula which I give in my memoir, and from proportional numbers taken from the memoir of Mr. Airy. The curves may be multiplied at will by choosing other measures of diameter than those I have given; I have traced a sufficient number of them for the requirements of my thesis. Here are the principal results drawn from them.

Instead of a deviation of 42° 16′ for the red rays, and 40° 29′ for the violet, which the first maximum should have presented, according to the theory of Descartes and that of Dr. Young, whatever may be the diameter of the drops, we find for a diameter of

Dev. 2	1st Maximum red	. 42° 3′	1st Maximum violet .	. 40° 20′
Dev. 1	,, ,,	. 41° 56′	,, ,, .	. 40° 14′
Dev. 5	,, ,,	. 40° 43′	,, ,, .	. 40° 6′
Dev. 2	,, ,,	. 41° 17′	,, ,, .	. 39° 47′
Dev. 0·1	,, ,,	. 40° 40′	,, ,, .	. 39° 22′
Dev. 0·05	,, ,,	. 39° 44′	,, ,, .	. 38° 43′
Dev. 0°·02	,, ,,	. 37° 41′	,, ,, .	. 37° 15¼′

The distance of the first maximum to the second is, in drops having

2	for the red rays . . .	32′	For the violet rays . . .	24′
1	,, ,, ,, . . .	53′	,, ,, ,, . . .	38′
0·5	,, ,, ,, . . .	1° 23′	,, ,, ,, . . .	58′
0·2	,, ,, ,, . . .	2° 36′	,, ,, ,, . . .	1° 48′
0·1	,, ,, ,, . . .	4° 6′	,, ,, ,, . . .	2° 50′
0·04	,, ,, ,, . . .	6° 25′	,, ,, ,, . . .	4° 31′

The progressive diminution of the diameter of the drops causes a continually increasing augmentation in the breadth of the first fringe and all the colours, and ends by their being superposed; such is the cause of the disappearance of the coloured rainbow in the clouds and fogs, and the origin of the white rainbow which afterwards disappears.

When the diameter of the globules, of which the fogs are formed, become less than 0·02 the millimetre, the same Table shows that the conditions favourable to the formation of the white rainbow, is, that the globules of the fogs have a diameter always between 0·1 and 0·02 of a millimetre. Moreover, if the diameter does not exceed 0·05 of a millimetre, the colours of all the fringes which follow the first, present themselves in a bow, from that in which they are produced under the latter, and

give birth to coloured crowns opposite the sun, a phenomenon which up to the present time remained unexplained. In support of views purely theoretical, which are developed at length, I bring first the experiments of Mr. Miller on threads of water of three different diameters, then the direct observations of Mr. Galle on the rainbow, afterwards my own experiments on very fine cylindrical threads of a viscous liquid, and finally, my observations on the coloured rainbows which are seen in cooled water, or on the irisation of the little cloud formed above hot water.

All these facts justify, fully and in all its details, the theory which I have propounded, and clearly show how illusory was the theory of the efficient rays of Descartes; the latter facts, above all, are a proof of the fallacy of the hypothesis of the vesicular state. They teach us what is the true constitution of clouds and fogs whose temperature is beyond zero Centigrade, and it is the only principle of interferences suitably employed which enabled me to establish it with certainty.

Towards the close of my memoir, I call the attention of physicists to certain singular facts, not yet explained, of interferences produced by very thin laminæ. I draw from these facts a most conclusive argument against the explanation which had been given of the suspension of the clouds by the hypothesis of vesicular vapours. For this reason, and for all the others which I have deduced against the truly singular hypothesis of the vesicular state, and against that of efficient rays, I dare hope these two hypotheses will be henceforward banished when teaching the sciences which they shackled; that they will never more be called to explain the suspension of clouds, the colours of the rainbow, the absence of the rainbow in clouds or fogs, but that we may confine ourselves to the explanations, free from every gratuitous supposition, which I have now given of these phenomena.

Meteorological Phenomena at Huggate, Yorkshire. By the Rev. T. Rankin.

On the Temperature of the Air registered at the 'Plover's' Winter-quarters at Point Barrow, in the Years 1852, 1853, 1854. *By* John Simpson, *M.D., R.N., F.R.G.S.*

This communication was brought under the notice of the Section by Prof. Haughton. The author commenced by saying that his attention was first directed to the importance of this subject, and he was induced to undertake the laborious task of hourly observations on the temperature in these regions, by certain remarks of Sir J. Richardson, at p. 331 of the ninth volume of the Royal Geographical Society's Journal, 1839, in reference to Sir D. Brewster's discussions of the hourly register of the temperature at Leith Fort. The author then stated that the observations had been continued from the 3rd of September, 1852, to the 7th of August, 1853, and for a few days before and after each of these dates in the neighbourhood, making a complete year, less 21 days; again, in precisely the same locality, from the 7th of September, 1853, to the 19th of July, 1854, to which have been added the first six days of September and one day, the 21st of July, during which the ship was in the immediate neighbourhood, making a second complete year, less 42 days. The ship returned to the same spot on the 27th of August, 1854, and remained four whole days, for which the hourly register gave a mean temperature of 39°·448, serving as a fair guide for estimating the temperature of the last eleven days of August. He then touched on the principle of an estimate for filling up the entire interval of twenty-one days in 1853, and proceeded to describe the instruments used, which were furnished by Adie and Co. of Edinburgh, and which, having been returned to the Hydrographer's office in 1855, could now be re-examined and compared with standards at Kew. The author then proceeded to give some highly interesting details of the freezing of the mercurial thermometers, and of the freezing of mercury exposed in open vessels; the temperature when it froze seemed about 39°. Prof. Haughton then proceeded to direct the attention of the Section to several interesting points, selected from the Journal and Tables, and concluded by describing two large sheets of curves of mean temperature: Fig. 1 showing the mean daily curve of temperature in the shade for each month of the year; also the mean daily curve of temperature in the sun for the month of June. Fig. 2 showed the mean daily curve of temperature for each season of the year for the summer and winter half-years, and for the whole year;

also the mean daily curve of temperature in the sun for forty-two days at Midsummer. The latitude at Point Barrow is 71° 21′ North, longitude 156° 17′ West.

On the Grand Currents of Atmospheric Circulation. *By* JAMES THOMSON, *C.E.*, *&c.*

In this paper Mr. Thomson brought under the notice of the Section a theory of the grand currents of atmospheric circulation, which had occurred to him. It has been ascertained as a matter of observation, that in latitudes extending from about 30° to the poles, the winds, while prevailing from west to east, prevail also in directions from the equator towards the poles. Now this motion towards the poles appears not to have been hitherto satisfactorily explained. In fact, it is the contrary motion to what is naturally to be expected when the theory of Halley, which was given about the year 1686, and which appears to afford the true key to the explanation of the trade-winds, is followed up with respect to the circulation of the air in other latitudes than those in which the trade-winds occur. According to this theory so applied, it would naturally be expected that the air, having risen to the upper regions of the atmosphere in a hot zone at the equator, should float towards the north and south polar regions in two grand upper currents, retaining, as they pass to higher latitudes, some remains, not abstracted by friction and admixture with the currents below, of the rapid equatorial motion of about 1000 miles per hour from west to east, which they had in moving with the earth's surface at the equator. Also, it would be expected that the air in the polar regions should have a prevailing tendency to sink towards the surface of the earth, in consequence of its increased density caused by cold; and that it should tend to flow from the polar regions along the surface of the earth, towards the equator, with a prevailing motion from west to east in advance of the earth, until, by friction and impulses on the earth's surface, the motion in advance of the earth, brought from above by the air in its descent, and communicated further to it by friction and admixture from above, as it passes to lower latitudes than its places of descent, is exhausted; or, in other words, until it reaches the latitude in which the trade-winds commence to blow from the east; and until it has communicated, in blowing from west to east on the earth's surface, a torsional force to the earth, just sufficient to balance the opposite torsional force communicated to the earth by the trade-winds blowing from east to west. Now this theory, obvious as it appears in the form just adduced, is found in one essential point to be controverted by observations. This point is what was stated in the outset of the present article, namely, that the prevailing winds on the surface of the earth in latitudes higher than 30°, are, while blowing from the west, as should be expected, found to blow more towards the poles than from the poles; and thus do not move as if impelled along the surface of the earth from polar to equatorial regions by an augmented pressure due to condensation by cold in polar regions, and a diminished pressure due to rarefaction in the equatorial regions. Observations being thus at variance with the only obvious theory proposed, the circumstance in question has been commonly regarded as rather paradoxical: and Lieut. Maury, one of the most recent writers on the subject, has, in his much-valued treatise on the Physical Geography of the Sea, found himself forced into supposing an entire reversal in latitudes above 30°, of the great circulation just described.

Mr. Thomson regards Lieut. Maury's supposition as being entirely unsupported by the known physical causes of the atmospheric motions. He, on the contrary, maintains that the great circulation already described does actually occur, but occurs subject to this modification, that a thin stratum of air on the surface of the earth in the latitudes higher than 30°—a stratum in which the inhabitants of those latitudes have their existence, and of which the movements constitute the observed winds of those latitudes—being, by friction and impulses on the surface of the earth, retarded with reference to the rapid whirl or vortex motion from west to east of the great mass of air above it, tends to flow towards the pole, and actually does so flow to supply the partial void in the central parts of that vortex, due to the centrifugal force of its revolution. Thus it appears that, in temperate latitudes, there are three currents at different heights:—that the uppermost moves towards the pole, and is part of a grand primary circulation between equatorial and polar regions;—that the lowermost moves

also towards the pole, but is only a thin stratum forming part of a secondary circulation;—that the middle current moves from the pole, and constitutes the return current for both the preceding;—and that all these three currents have a prevailing motion from west to east in advance of the earth. This is the substance of Mr. Thomson's theory; and he gives, as an illustration, the following simple experiment:—If a shallow circular vessel with flat bottom, be filled to a moderate depth with water, and if a few small objects, very little heavier than water, and suitable for indicating to the eye the motions of the water in the bottom*, be put in, and if the water be set to revolve by being stirred round, then, on the process of stirring being terminated, and the water being left to itself, the small particles in the bottom will be seen to collect in the centre. They are evidently carried there by a current determined towards the centre along the bottom in consequence of the centrifugal force of the lowest stratum of the water being diminished in reference to the strata above through a diminution of velocity of rotation in the lowest stratum by friction on the bottom. The particles being heavier than the water, must, in respect of their density, have more centrifugal force than the water immediately in contact with them; and must therefore in this respect have a tendency to fly outwards from the centre, but the flow of water towards the centre overcomes this tendency and carries them inwards; and thus is the flow of water towards the centre in the stratum in contact with the bottom palpably manifested.

On the Plasticity of Ice. *By* James Thomson, *C.E. &c.*

Mr. Thomson commenced by stating, that to Prof. James Forbes is to be attributed the discovery that the motion of glaciers down their valleys depends on a plastic or viscous quality of the ice. He (Mr. Thomson) had formed a theory to explain the nature of this plasticity, and the manner in which it originates. He had been led to his speculations on this subject from a previous theoretical deduction at which he had arrived, namely, that the freezing-point of water, or the melting-point of ice, must vary with the pressure to which the water or the ice is subjected, the temperature of the freezing-point being lowered as the pressure is increased. His theory on that matter† led to the conclusion that the lowering of the freezing-point for one additional atmosphere of pressure must be 0°·0075 Centigrade, and that the lowering of the freezing-point corresponding to other pressures must be proportional to the additional pressure above one atmosphere. The phenomena which he thus predicted, in anticipation of direct observations, were afterwards fully established by experiments made by his brother, Prof. William Thomson, of which an account was published in the 'Proceedings of the Royal Society of Edinburgh for February 1850.' Having thus laid down as a basis the principle of the lowering of the freezing-point of water by pressure, Mr. Thomson proceeded to offer his explanation, derived from it, of the plasticity of ice at the freezing-point, as follows:—If to a mass of ice at 0° Centigrade, which may be supposed, for the present, to be slightly porous, and to contain small quantities of liquid water diffused through its substance, forces tending to change its form be applied, whatever portions of it may thereby be subjected to compression will instantly have their melting-point lowered so as to be below their existing temperature of 0° Centigrade. Melting of those portions will therefore set in throughout their substance, and this will be accompanied by a fall of temperature in them, on account of the cold evolved in the liquefaction. The liquefied portions being subject to squeezing of the compressed mass in which they originate, will spread themselves out through the pores of the general mass, by dispersion from the regions of greatest to those of least fluid pressure. Thus the fluid pressure is relieved in those portions in which the compression and liquefaction of the ice had set in, accompanied by the lowering of temperature. On the removal of this cause of liquidity, the fluid pressure, namely, the cold, which had been evolved in the compressed parts

* A few tea-leaves taken from a teapot will suit the purpose well.

† This theory is to be found in a paper by the author, entitled "Theoretical Considerations on the Effect of Pressure in lowering the Freezing-point of Water," published in the Transactions of the Royal Society of Edinburgh, vol. xiv. part 5, 1849, and also re-published in the Cambridge and Dublin Mathematical Journal for Nov. 1850, vol. v. p. 248.

of the ice and water, freezes the water again in new positions, and thus a change of form, or plastic yielding of the mass of ice to the applied pressures, has occurred. The newly-formed ice is at first free from the stress of the applied forces, but the yielding of one part always leaves some other part exposed to the pressure, and that part, in its turn, melts and falls in temperature; and, on the whole, a continual succession goes on, of pressures being applied to particular parts—liquefaction occurring in those parts accompanied by evolution of cold,—dispersion of the water so produced in such directions as will relieve its pressure,—and re-congelation, by the cold previously evolved, of the water on its being relieved from this pressure. The cycle of operations then begins again, for the parts re-congealed, after having been melted, must, in their turn, through the yielding of other parts, receive pressures from the applied forces, thereby to be again liquefied, and to proceed through successive operations as before. The succession of these processes must continue as long as the external forces tending to change of form remain applied to the mass of porous ice permeated by minute quantities of liquid water. The ice is thus shown to be incapable of opposing a permanent resistance to the pressures, and to be subject to gradual changes of form while they act on it; or, in other words, it has been shown to be possessed of the quality of plasticity. In the foregoing, I have supposed the ice under consideration to be porous, and to contain small quantities of liquid water diffused through its substance. Porosity and permeation by liquid water are generally understood, from the results of observations, and from numerous other reasons, to be normal conditions of glacier ice. It is not, however, necessary for the purposes of my explanation of the plasticity of ice at the freezing-point, that the ice should be, at the outset, in this condition; for even if we commence with the consideration of a mass of ice perfectly free from porosity, and free from particles of liquid water diffused through its substance, and if we suppose it to be kept in an atmosphere at or above 0° Centigrade, then, as soon as pressure is applied to it, pores occupied by liquid water must instantly be formed in the compressed parts, in accordance with the fundamental principle of the explanation which I have proposed—the lowering, namely, of the freezing- or melting-point, by pressure, and the cognate fact, that ice cannot exist at 0° Centigrade under a pressure exceeding that of the atmosphere. I would further wish to make it distinctly understood, that no part of the ice, even if supposed at the outset to be solid, or free from porosity, can resist being permeated by the water squeezed against it from such parts as may be directly subjected to the pressure; because, the very fact of that water being forced against any portions of the ice supposed to be solid, will instantly subject them to pressure, and so will cause melting to set in throughout their substance, thereby reducing them immediately to the porous condition. Thus it is a matter of indifference, as to whether we commence with the supposition of a mass of porous or of solid ice.

Mr. Thomson then referred to an experiment made by Prof. Christie, late Secretary to the Royal Society, showing the plasticity of ice in small hand specimens, and also to more recent experiments by Prof. Tyndall to the same effect, and very interesting on account of the striking way in which they exhibit the phenomena. He also stated that another very important quality of ice was brought forward by Faraday in 1850 (see 'Athenæum,' No 1181). It was that two pieces of moist ice will consolidate into one on being laid in contact with one another, even in hot weather. The theory he had just propounded, he said, afforded a clear explanation of this fact as follows:—The two pieces of ice, on being pressed together at their point of contact, will, at that place, in virtue of the pressure, be in part liquefied and reduced in temperature, and the cold evolved in their liquefaction will cause some of the liquid film intervening between the two masses to freeze. It is thus evident, he added, that by continued pressure fragmentary masses of ice may be moulded into a continuous mass; and a sufficient reason is afforded for the reunion, found to occur in glaciers, of the fragments resulting from an ice cascade, and for the mending of the crevasses or deep fissures which result occasionally from their motion along their uneven beds.

Secular Variations in Lunar and Terrestrial Motion from the influence of Tidal Action. By D. Vaughan, *of Cincinnati, Ohio.*

Laplace concludes from his elaborate investigations, that the rotation of the earth

is not affected by the occurrence of the tides; nor do his formulæ reveal any permanent alteration in the motion of the lunar orb which disturbs the repose of our oceans. These results, announced by so high an authority, might be received without a careful examination if the fundamental principles of natural philosophy did not discountenance the idea of an actual creation of power by lunar attraction. The tides constitute an important mechanical agent; and, could their whole force be rendered available, it would be found adequate to several hundred times the labour of the human population. So great an amount of motive power, whether appropriated to the great purposes of nature and art, or wasted in overcoming friction, cannot be produced without some expense; and my present object is to trace the change which it involves in the motions of the earth and the moon. As the extreme disproportion between the momentum of the oceanic waters and that of the planetary bodies is the chief source of error in these investigations, I shall commence by showing how the tidal action should operate, if the moon moved around the earth in an exact circle, situated in the plane of the equator, and not more than 34,000 miles in diameter. Her periodical revolution in this case would occupy nearly twelve hours, and the lunar day would be about twenty-four hours in length. The tidal action on the seas nearest to the moon would be almost twice as great as on those most distant; the former being about 5000 times, and the latter over 2500 times, the disturbing action now exerted by the moon on the watery domain. The aqueous appendage of our planet would in this case form two great moveable oceans, sustained on its opposite sides by the attraction of our satellite, and keeping pace with her movements. Without taking into consideration the oscillations of the solid part of the earth which might possibly occur in these circumstances, it is evident that there should be a general flow of the waters from west to east; and though the current may be alternately reversed in deep channels, the force propelling it in an eastern direction should always maintain the ascendency. A vast body of water, circulating around the earth from west to east, could not fail to accelerate its rotary motion; although the result would not be exhibited by the formulæ of Laplace. The moon in this case would sustain a loss of momentum to a more considerable extent. It is well known that the attraction of mountains modifies the direction of terrestrial gravity in their vicinity; and that a plumb-line on that part of the equator immediately west of the Andes would be slightly deflected to the east. In the case we have supposed, the direction of terrestrial gravity would experience a similar deflection at places in conjunction with the moon from the attraction of the excess of waters which swelled behind her. Accordingly, the lunar orb would be drawn, not directly to the earth's centre, but always to a point a little westward of it, and a constant loss of motion would be an inevitable consequence. It would be different if the earth could preserve an invariable form, for in that case its attraction on a satellite being always directed to the centre, or alternately deflected east and west of that point, the loss and gain of motion should be evenly balanced after one or many revolutions. Other investigations lead to the same conclusion. A satellite revolving just beyond the confines of our atmosphere, would alternately accelerate and retard the movements of one more distant; and physical astronomy shows that in our planetary systems a like periodicity results from the inequality of the times in which the several planets perform their revolutions. But as the tide-wave rolls around the earth with the same mean angular velocity as the moon, their mutual action will not exhibit the periodicity which characterizes planetary disturbances. In the analytical solution of this problem, the equation depending on the difference of motion of the moon and the tide-wave would acquire by integration a divisor infinitely small; and this proves its secular character. If Laplace finds no such divisors, it is because all the modifications in the action of the moon on the waters of the ocean are not embraced in his investigations on the subject. Leaving the supposed case, we shall now pass to the actual condition of the agencies concerned in tidal phenomena on our globe. At her present distance the revolution of the moon occupies more time than the earth's period of rotation; and the tidal wave which has the greatest disturbing influence being always east of our satellite, must add to its velocity, while it retards that of the earth. We may remark, however, that the additional velocity imparted to the moon would give her a larger orbit, and increase the period of her revolution. Hence the orbital motion of the moon, as well as the rotary motion of the earth, sustain a loss depending on the difference of the tidal force on opposite sides of our globe, and so very insignificant, that some mil-

lions of years would be required to cause a reduction of one per cent. in the momenta of these vast bodies. I must however question the results of Laplace, who finds that the change in the length of the day has not amounted to the $\frac{1}{100}$th part of a second during the last 2000 years. This conclusion is based on a comparison of ancient and modern eclipses; and the time of the earth's rotation is thus ascertained from the revolutions of the moon, making corrections for the disturbances operating on the latter body. But all the disturbing influences have not yet been taken into consideration; and as the one noticed in the present article operates on the earth and moon, we cannot regard either of these bodies as an infallible chronometer for measuring the vast ages of eternity.

On the Light of Suns, Meteors, and temporary Stars. *By* D. Vaughan, *Cincinnati, Ohio.*

Modern science recognizes shooting-stars, fire-balls, and meteoric stones as bodies which enter our atmosphere from external space with immense velocities. From the great elevation at which these objects are luminous, it has been inferred that their light has little or no dependence on aërial action; and indeed the presence of the air alone could not account for the greatness of the illumination which marks their approach to the earth, but ceases when they enter the dense stratum of the atmosphere. The diameter of many luminous meteors has been estimated at two or three thousand feet; and the globe of light which they exhibited must have been several million times greater than the largest meteoric stone yet found on the earth's surface. It is supposed that these brilliant exhibitions are produced by cosmical masses several hundred yards in diameter, which, in traversing the planetary regions, occasionally sweep through the verge of our atmosphere, and, after casting a few fragments on the earth, continue their course through space. But the idea that such wandering bodies should graze our planet so often, without ever striking it directly or falling to its surface, is too extravagant to be seriously entertained. It would be far more likely that, during a naval engagement, a ship should be almost touched by several thousand balls, without being ever struck by a single one. Moreover, there is not the slightest evidence that meteorites ever perform such remarkable feats of precision, or experience so many narrow escapes from a collision with the earth; for, instead of being observed departing into space, they suddenly disappear after their encounter with the air. The small amount of solid matter which falls to the ground on these occasions is justly regarded as inadequate to evolve so vast a body of light by acting on the rarefied air at great elevations; but our globe seems to be invested with an atmosphere of æther having far more wonderful properties. Astronomical investigations prove the existence of a rare medium pervading all space; and this subtle fluid cannot be wholly insensible to chemical forces, which alone could render it useful in nature's economy. Extreme rarity would, indeed, prevent it from undergoing any chemical change in the interplanetary regions; but it is compressed to a much greater density about the vast spheres by which space is tenanted. The atmospheres of this fluid enveloping the earth and the other large planets, are not sufficiently dense for chemical action, except in cases where they receive an additional pressure from meteoric bodies sweeping through them with wonderful rapidity. The evolution of light on such occasions depends, not only on the size and velocity of the falling mass, but also on the direction in which it approaches the planetary surface; and observation shows that the most brilliant meteors move very nearly parallel to the horizon. But around the sun a much stronger attractive force gives this ethereal fluid the compression necessary for a constant chemical action, and a steady development of light; while the realms of space furnish inexhaustible supplies of the luciferous matter, and impart perpetual brilliancy to the great luminary of our system. It is not possible that the self-luminous condition of the sun could be maintained by any combustible, or light-yielding matter; of which it is composed. From a comparison of the relative intensity of solar, lunar, and artificial light, as determined by Euler and Wollaston, it appears that the rays of the sun have an illuminating power equal to that of 14,000 candles, at a distance of one foot; or of 3500,000000,000000,000000,000000 candles, at a distance of 95,000,000 miles. It follows that the amount of light which flows from the solar orb could be scarcely produced by the daily combustion of 700 globes of tallow, each equal to the earth in magnitude. A sphere of combustible matter much larger than the sun itself should

be consumed every ten years in maintaining its wonderful brilliancy, and its atmosphere, if pure oxygen, would be expended before a few days in supporting so great a conflagration.

An illumination on so vast a scale could be kept up only by the inexhaustible magazine of æther disseminated through space, and ever ready to manifest its luciferous properties on large spheres, whose attraction renders it sufficiently dense for the play of chemical affinity. Accordingly, suns derive the power of shedding perpetual light, not from their chemical constitution, but from their immense mass and their superior attractive power. We thus obtain some definite knowledge respecting the stupendous magnitude of the fixed stars; and making due allowance for their density, we may confidently pronounce the smallest stellar body several thousand times greater than the globe we inhabit. This theory gives considerable support to the views which many astronomers maintain, on different grounds, in regard to the relative brilliancy of the stars; for it appears that, though the self-luminous occupants of space are not necessarily equal in size, they differ much less than we might anticipate from an acquaintance with the members of our planetary system. That the light of the sun is furnished, not by its solid or liquid matter, but by its luminous atmosphere, has been proved very conclusively from the observations with Arago's polarizing telescope. There is also evidence that this luciferous envelope is constantly replenished by supplies of æther from space. The sun's rotation assists in effecting this object by expelling the fluid from its equatorial regions, and thus creating a corresponding influx at its poles. A displacement by this means would evidently cause the solar atmosphere to advance constantly from its poles to its equator; and such a movement is indicated by the change in the position of the sun's spots, which, according to the observations of Peters for many years, are continually diminishing their heliocentric latitude. The progressive motion of the solar orb through space tends also to replenish its atmosphere with fresh material for the maintenance of its light; and the position of the large planets has some influence on the amount of æther which it receives from the celestial domain. The periodicity observed in the solar spots, and some changes exhibited by many variable stars, may be ascribed to an effect of this kind. But the result would be far more decided if a sun had large planets in its immediate vicinity; for the attraction of these bodies would alter the pressure on its æthereal atmosphere, and produce a corresponding variation in the development of its light. On this principle we may explain several phenomena connected with the variable stars; and I may remark, that Argelander regards many of their peculiarities as indicating, that planets revolving around some suns affect the generation of light in their photospheres. But a planet revolving in an orbit of the smallest size possible would be productive of more remarkable consequences. Sweeping through the æthereal atmosphere of the great central sphere, it would impart a sufficient degree of pressure for luciferous action; and exhibit, on a grand scale, the evolution of light which accompanies the visits of meteoric masses to the earth. From the great brilliancy of meteors which move in a horizontal direction, it is evident that a satellite revolving around a large globe, at a small distance above its surface, should be favoured with all the conditions necessary for a sublime meteoric illumination; and it is probable that some of the bright tenants of space may shine by light originating from such a cause. Indeed, the resistance of the space-pervading medium must constantly diminish the orbits of all satellites, and, after innumerable years, bring them into such a proximity with their central bodies that such grand meteoric phenomena would be almost inevitable. If space contain dark systems (as is generally believed), the central orb which presides over each of them would become luminous, when one of its planets was passing through the final state of existence.

In a paper read at the last meeting of the American Association for the Advancement of Science, and published in the 'Proceedings' (pp. 111—113), I have shown that the stability of satellites could no longer exist if their orbits were reduced to a certain limit; and that the attraction of the primary body would render them incapable of preserving a planetary form. In like manner, a member of one of the dark systems of space, when brought too near its central orb, would be likewise doomed to suffer a dismemberment; and the fragments resulting from the mighty wreck would immediately scatter into separate orbits. Instead, therefore, of closing its planetary career as one vast meteor, the attendant should form a host of meteoric masses, and thus send forth far greater floods of light into space. But the frag-

ments, gradually assuming circular orbits, would ultimately form a ring similar to that around Saturn; and as this change advanced, the light should constantly decline until it ceased when the æther partook of the motion of the fragmentary host, and became almost insensible to their pressure. It is to occurrences of this kind, which must occasionally take place in the wide domains of creation, that we may ascribe the appearance of temporary stars, and in doing so, we obtain a satisfactory explanation of the various peculiarities which they exhibit. The existence, on our own sphere, of the æther which acts so important a part in the scene of celestial wonders is indicated by certain electrical phenomena. On its presence seems to depend the evolution of light attending the passage of electricity through the vacuum of an exhausted receiver, and the light of the aurora borealis appears to be evolved by electric action from the æthereal fluid, which arrives at the polar regions from space. It is only by this hypothesis that we can account for the effect of a shooting-star during an aurora, in lighting up certain parts of the vaults of heaven not previously illuminated (see Humboldt's 'Cosmos' on Aërolites). It thus appears that the subtle medium which fills space is not to be regarded as a mere impediment to planetary motion, but as a useful agent in the course of Nature's operations, and as indispensable to our existence as the appendages of air and water which roll around our planet.

CHEMISTRY.

On Ozone. By Professor T. Andrews.

On the Heat of Combination of Acids and Bases. By Professor Andrews.

On the Amount of Nitrogen in the Algæ. By Professor James Apjohn, *M.D.*

On some Compounds of Cyanogen. By Professor James Apjohn, *M.D.*

On the Composition of the Iron Ores of the Leitrim Coal Field, with some Remarks on the Advantages of that District for the Manufacture of Iron. By P. Buchan.

On the Condition of Thames Water, as affected by London Sewage. By R. Barnes, *M.D. and* W. Odling, *M.B., F.C.S.*

The authors had, for a period of nearly six months, made consecutive weekly examinations, microscopical and chemical, of Thames water, taken at high and low tide from the middle of the stream at Greenwich. From their experiments it appeared that the pouring in of the contents of drains did not affect Thames water so seriously as was generally considered, inasmuch as the greater part of the sewage become destroyed by the innoxious processes of oxidation and vital development, while only a small portion underwent the process of putrefaction, properly so called. The amount of organic matter present did not appear to be any criterion of the offensiveness of the water, seeing that it existed for the most part in the state of living organisms. The authors found invariably a greater amount of organic matter in high, than in low water.

On Urea as a Direct Source of Nitrogen to Vegetation. By Charles A. Cameron, *M.D.*

The author showed that nitrogen was as available as food for plants, when a constituent for urea, as in its ammoniacal combination; or, in other words, that urea, without being converted into ammonia, may be taken up into the organisms of plants, and there supply the necessary quantity of nitrogen. He described the experiments which led him to this conclusion, which were very elaborate, and were made on barley plants grown in non-nitrogenous soils, and in confined spaces supplied with air freed from ammonia. The following conclusions were deducible from the results of his experiments, viz.—1. That the perfect development of barley can take place, under

certain conditions, in soil and air destitute of ammonia and its compounds. 2. That urea in solution is capable of being taken unchanged into the organisms of plants. 3. That urea need not be converted into ammonia before its nitrogen becomes available for the purposes of vegetation. 4. That the fertilizing effects of urea are not at all inferior to those of the salts of ammonia. 5. That there exists no necessity for allowing drainings or other fertilising substances containing urea to ferment; but that, on the contrary, greater benefits must be derived from their application in the recent or unfermented condition.

On a Method of Refining Sugar. By Professor Daubeny, *M.D., F.R.S.*

Dr. Daubeny gave an account of a new method of refining sugar, conducted at Plymouth by Mr. Oxland, and known by his name. It consists in the adoption of the superphosphate of alumina in conjunction with animal charcoal, as a substitute for the albumen usually employed for that purpose. In both cases the object is to separate and carry down the various impurities, which colour and adulterate the pure saccharine principle, present in the syrup expressed from the cane or other vegetable which supplies it. As, however, bullocks' blood is the material usually procured for the purposes of supplying the albumen, a portion of uncoagulated animal matter, together with certain salts, is left in the juice in the ordinary process of refining, which impairs its purity, and promotes its fermentation—thus occasioning a certain loss of saccharine matter to result. Nothing of the kind happens when the superphosphate is substituted, and so much more perfect a purification of the feculent matters, under such circumstances, takes place, that several varieties of native sugar, which, from being very highly charged with feculent matters, would be rejected in the ordinary process of refining, are readily purified by this method. The employment of superphosphate of alumina also gets rid of so much larger a proportion of the impurities present in the sugar, that much less animal charcoal is subsequently required for effecting its complete defecation, than when bullocks' blood has been resorted to. The quantity of superphosphate necessary for effecting the object is, for ordinary sugars, not more than twelve ounces to the ton; whereas, for the same quantity, as much as from one to four gallons of bullocks' blood is found to be required. Dr. Daubeny suggested that this reagent might be advantageously resorted to, not only in the purification of sugar, but also in other processes of the laboratory, when the removal of foreign matters, intimately mixed with the solution of a definite compound, becomes a necessary preliminary to its further examination.

On the Conversion of Paper into Parchment. By Professor Daubeny, *M.D., F.R.S.*

Dr. Daubeny exhibited some specimens of paper that had been converted into parchment. The discovery, he believed, had originated in the experiments made in connexion with the manufacture of gun-cotton, as it was accidentally discovered, when dipping paper into nitric acid, that the same effect was not exercised upon it as upon the cotton, but that it was rendered tough. The alteration visible in the conversion of common paper into parchment after being dipped into weak sulphuric acid, is believed to be attributable to the substitution of an atom of water for an atom of hydrogen.

On Hygrometers and Hygrometry, with a description of a New Modification of the Condenser Hygrometer and Hygroscope. By M. Donovan, *M.R.I.A.*

Suggestions towards a more Systematic Nomenclature for Organic Bodies. By G. C. Foster, *B.A., F.C.S.*

Classification.—The classification on which the author proposes to base a systematic nomenclature for organic compounds, is a modification of that employed by Gerhardt in his 'Traité de Chimie Organique.' It consists in arranging chemical substances in a number of groups or families, the individual members of each of which have analogous relations to each other. The relations existing between the various groups can be most easily explained by comparing corresponding terms of each. For instance, assuming that each group contains a hydrocarbon analogous to olefiant gas,

$C^2 H^4$, all these hydrocarbons may be represented by the formula $x(CH^2)$, or by the formula $x(CH^2)-y\,H^2$, x and y being whole numbers. The substances represented by the first of these formulæ are called by Gerhardt *homologous*; they evidently differ in composition by a multiple of CH^2. Mr. Foster proposes to call substances *isologous*, which, like the hydrocarbons represented by the second formula (x being constant, and y variable), possess similar chemical functions, and differ in composition by a multiple of H^2. In the following Table,

$C\,H^2$						
$C^2 H^4$	$C^2 H^2$					
$C^3 H^6$	$C^3 H^4$	$C^3 H^2$				
$C^4 H^8$	$C^4 H^6$	$C^4 H^4$	$C^4 H^2$			
$C^5 H^{10}$	$C^5 H^8$	$C^5 H^6$	$C^5 H^4$	$C^5 H^2$		
$C^6 H^{12}$	$C^6 H^{10}$	$C^6 H^8$	$C^6 H^6$	$C^6 H^4$	$C^6 H^2$	
$C^7 H^{14}$	$C^7 H^{12}$	$C^7 H^{10}$	$C^7 H^8$	$C^7 H^6$	$C^7 H^4$	$C^7 H^2$

the formulæ in each vertical column represent *homologous* substances, those in the same horizontal line represent *isologous* substances. The relations which exist between the hydrocarbons, also exist between the other corresponding terms of the various groups, and therefore between the groups themselves taken collectively. Each group may therefore be characterized by the homologous and isologous series to which it belongs.

In attempting to enumerate the most important members of each group, it will save time to take at once a particular instance—for example, the third group of the first homologous series, namely the propylic or tritylic group. Here we have the three following alcohols:—

1. Propylic alcohol, $C^3 H^8 O$ (monatomic).
2. Propylic glycol, $C^3 H^8 O^2$ (diatomic).
3. Glycerine, $C^3 H^8 O^3$ (triatomic).

The replacement of more or less hydrogen in these alcohols by equivalent quantities of oxygen, gives a number of acids; those derived from the first being unibasic, those from the second bibasic, those from the third terbasic. The following are the acids so formed, together with the alcohols from which they are formed:—

$C^3 H^8 O$ propyl. alc., $C^3 H^6 O^2$ propion. ac., $C^3 H^4 O^3$ pyruvic ac., $C^3 H^2 O^4$ (unknown),.. unibasic.
$C^3 H^8 O^2$ propyl. glyc., $C^3 H^6 O^3$ (unknown), $C^3 H^4 O^4$ nicotic ac.?, $C^3 H^2 O^5$ me. oxalic ac., bibasic.
$C^3 H^8 O^3$ glycerine, $C^3 H^6 O^4$ (unknown), $C^3 H^4 O^5$ (unknown), $C^3 H^2 O^6$ (unknown).. terbasic.

The alcohols may be regarded as the leading members of each group. Around each of them and their derived acids, various chlorides, anhydrides, nitrides, and other bodies of which these are typical, are to be placed.

Nomenclature.—In the nomenclature here proposed, the root of the name of any substance denotes the group to which it belongs, the termination, its place in the group, or its chemical function. The root is, in most cases, formed by the combination of two Greek numerals; the first denoting the *homologous*, the second the *isologous* series to which the substance belongs*. Thus, allylic alcohol, $C^3 H^6 O$, belongs to the second homologous and to the third isologous series, counting from above downwards, and from left to right in the Table of hydrocarbons given above; it therefore belongs to the *deutritic* group. Similarly, angelic acid, $C^5 H^8 O^2$, belongs to the *deupentic* group, that is, to the second group of the fifth isologous series, or to the fifth group of the second homologous series.

The following are the terminations suggested to denote some of the best defined chemical functions:—

-yl denotes a monatomic radical: Example—Tetrexyl $=C^6 H^5=$phenyl.

-ene denotes a diatomic radical: Example—Penteptene$=C^7 H^6=$radical of chlorobenzol (Wicke, Ann. Ch. Pharm. cii. 358).

-ise denotes a triatomic radical: Example—Tritise$=C^3 H^5=$glyceryl.

-ylia denotes nitride of -yl: Example—Tetrexylia (or tetrexia)†$=C^6 H^7 N=$nitride of tetrexyl.

* Only so much of each numeral is used as is necessary to characterize it distinctly, and for convenience of pronunciation. In the case of bodies of the first homologous series, the names express only the isologous series to which they belong. Thus, the names of the methyl, ethyl, propyl, ... compounds are formed from the roots *prot-*, *deut-*, *trit-*, ... instead of from *proprot-*, *prodeut-*, *protrit-*, ...

† The syllable *yl* may be omitted when it is followed by an additional termination.

-enia denotes nitride of -ene: Example—Deutenia=$C^2 H^5 N$=nitride of deutene (acetylamine, Natanson and Cloez).

-isia denotes nitride of -ise: Example—Deutisia=$C^2 H^3 N$=nitride of deutise= acetonitrile.

The vowels *a, e, i,* &c. before a functional termination denote respectively the replacement of H^2 by O, H^4 by O^2, H^6 by O^3, &c., as deutyl $C^2 H^5$, deutaÿl $C^2 H^3 O$, deutene $C^2 H^4$, deuteëne $C^2 O^2$.

The acids derived from the hydrates of -yl, -ene, and -ise, respectively, by the replacement of H^2 by O, are -ic acid, -eric acid, -isic acid: examples, penteptic =$C^7 H^6 O^2$=benzoic, pentepteric=$C^7 H^6 O^3$=salicylic.

The acids derived from the alcohols by the replacement of H^4 by O^2, or from the last-mentioned acids by the replacement of H^2 by O, are respectively, -aïc, -eraïc, -isaïc: examples, nonaïc = $C^9 H^{16} O^3$ = coumaric, noneraïc = $C^9 H^{16} O^4$ = anchoïc, tetreptisaïc=$C^7 H^6 O^5$=gallic.

The acids formed by the replacement of H^6 by O^3, are -eïc, -ereïc, -iseïc: examples, tritocteïc=$C^8 H^8 O^4$=orsellic, tritereïc=$C^3 H^2 O^5$=mesoxalic, deutexiseïc =$C^6 H^6 O^6$=aconitic. The names of the unibasic acids therefore terminate in -ic, -aïc, -eïc; those of the bibasic acids in -eric, -eraïc, -ereïc; and those of the terbasic acids in -isic, -isaïc, -iseïc. Chlorine, bromine, and iodine substitution products are denoted by the syllables chlo-*, bro-, io-, prefixed to the names of the hydrogen compound from which they are derived; as chlodeutene=$C^2 H^3 Cl$, brotetrexia= $C^6 H^6 BrN$=bromaniline. Multiplication is in all cases expressed by *Latin* numerals; as terchlodeutic acid=$C^2 HCl^3 O^2$=(*tri*chloracetic), biprotylia (or biprotia)=$C^2 H^7 N$ =dimethylamine.

In devising these names, the author has tried to avoid using expedients which are not recommended by being already partially in use amongst chemists. It is evident that the system of nomenclature proposed is very far from complete: it is intended only as a suggestion of the way in which a more complete system might be formed. The author's object has been to propose rules by which intelligible names may be given to new bodies, not to improve on those already attached to known substances.

On some Arseniates of Ammonia. By ALPHONSE GAGES.

After mentioning the arseniates of ammonia already described by Berzelius and Mitscherlich, and noticing the imperfect description given in books about the processes for preparing the salts of ammonia and arsenic acid, and the doubtful character of their constitution, the author described his own experiments, which verified the constitution of the salts mentioned by Berzelius and Mitscherlich: he found, however, that the salt containing three equivalents of ammonia described by the former, contains seven equivalents of hydrated water. He described three new double salts, formed by arseniate of ammonia, in which soda, potash, &c. act as the second bases. He also exhibited some beautifully crystallized compounds of arsenic acid, with morphia and quinine, which may probably be of interest as therapeutical agents.

On the Specific Gravity of Chloride of Nitrogen, with some Remarks upon its Action on Alcohol. By ALPHONSE GAGES.

The author gave determinations which were extremely close to those given many years ago by Sir Humphry Davy. He also mentioned the fact that chloride of nitrogen dissolves in absolute alcohol without decomposition, but if the solution be allowed to stand for a few hours it decomposes. He described an apparatus for introducing the chloride of nitrogen into the alcohol, and mentioned the character of the reaction which took place.

Chemical Notes. By J. H. GLADSTONE, *Ph.D., F.R.S.*

1. *On Explosive Potassium.*—Dr. Gladstone related how on one occasion a piece of potassium had exploded in his hands with much flame, noise, and violence. On examining the specimen afterwards, he found that it contained hard pieces which consisted of the compound of carbonic oxide and potassium, and were convertible by

* Comp. Daubeny, Brit. Assoc. Rept., 1851, p. 124.

water into rhodizonate of potash, a substance known to be explosive. The specimen contained no rhodizonate ready formed.

2. *On Froth.*—Some liquids when shaken with air form a more or less permanent froth. Aqueous solutions of organic bodies are peculiarly disposed to do so. The frothing of beer is due originally in a great measure to the carbonic acid that rises through the liquid, but its persistence is quite independent of that or any other dissolved gas, as was proved by exhausting some beer by an air-pump, and afterwards shaking it. Acetates are much given to making a permanent froth when dissolved in water, whether the solution contain air or not; yet acetic acid itself is not remarkable for this quality, and alcohol or æther forms bubbles when shaken which instantly disappear. The power of producing a persistent froth appears to be a specific quality not depending on the density of the liquid or any other known property. The colour of froth is always lighter than that of the liquid from which it is produced, and in some cases it is totally different. The author showed that this was due to the dichromatism of such liquids; for instance, a thin stratum of cochineal transmits rays which are absorbed by a larger quantity of the substance. In a similar manner the colourless bubble that floats on port wine was explained by a prismatic analysis.

On the Decomposition by Heat of certain Ammoniacal Salts. *By* J. H. Gladstone, *Ph.D., F.R.S.*

The author showed that the decomposition of phosphate and sulphate of ammonia by a strong heat was not entirely owing to the non-volatility, unless at a very high temperature, of phosphoric and sulphuric acids. In fact these salts are decomposed partially when their solutions are boiled, ammonia being given off, and the remaining liquor becoming acid. In like manner oxalate of ammonia is capable of decomposition, and crystals of the citrate give off the volatile alkali even at the ordinary temperature, acquiring at the same time an acid reaction. It was noticed that the ammonia salts of the monobasic hydrochloric and nitric acids are not decomposable by water, while the compounds of the bibasic, oxalic, and sulphuric acids are liable to partial decomposition, and those of the tribasic, phosphoric, and citric acids are still more easily resolved into free ammonia and acid salts.

On the Use of the Prism in detecting Impurities. *By* J. H. Gladstone, *Ph.D., F.R.S.*

This paper described the novel use of the prism in detecting impurities. The author described the methods of examining substances by means of a prism, especially the instructive results obtained with liquids when the ray of light traverses them in a wedge-shaped vessel. He suggested this as a means of detecting coloured impurities when they do exist, and of proving their absence when they are wrongfully suspected. He showed the value of the means in respect to coloured confectionery, tea, and mustard, and remarked on its use in examining wines, liqueurs, pigments used in the fine arts, gems, pharmaceutical preparations, &c. He stated that the prism and hollow wedge were already used as a commercial means of ascertaining the purity of certain substances.

On Electrical Currents in the Earth's Surface. *By* Archibald H. Hamilton.

In the spring of the present year, the author had occasion to try a series of experiments on a difficult point, namely, the nature of the earth as a conducting body. Having selected six convenient stations, represented in the diagram, he buried different metallic bodies in those marked A, B, C, D, and wooden boxes, filled with water, in which metal plates were to be plunged, at stations No. 1 and No. 2; these stations were connected by wires sufficiently insulated to convey currents of a single cell, without sensible loss in ordinary weather.

On the evening of April 20, 1857, about 6·30 P.M., he proceeded to make some observations with a small galvanometer. He first connected a brass plate in box No. 1 with the brasses buried at A and B, and found a strong deflection, arising as it were from *zinc* plates at A and B. He then took down the galvanometer to C, and connected by its wire the plates buried at C with a zinc plate plunged in No. 2, and

observed that, instead of a current flowing *from* the *less* oxidable metals ($Cu+\frac{1}{5}Sn$) *into* the *more* oxidable (Zn), there was a strong current flowing *from* the *zinc* into the copper and tin plates buried at C.

This unlooked-for current, by stopping the source of his motive power (for there was no battery-power to be used in these experiments), forcibly diverted his attention from the original experiments, to the examination of this new and curious phenomenon. He accordingly endeavoured, by enlarging the number of the stations, &c., and especially by using wooden boxes or porous earthen vessels buried in the ground and open at the top, and plates of the *same* metal, numbered for identification, and *interchanged* as frequently as possible, to obtain some rudiments of laws for these curious currents. Owing to the difficulties of the experiments, and the incompleteness of the apparatus, the following results are presented merely as agreeing with the general tenor of the observations, and affording a basis for laws to be deduced from more extended and accurate experiments.

1. There will be, almost always, a current flowing along an insulated wire, joining two plates of the same metal, similarly buried in the surface of the earth.

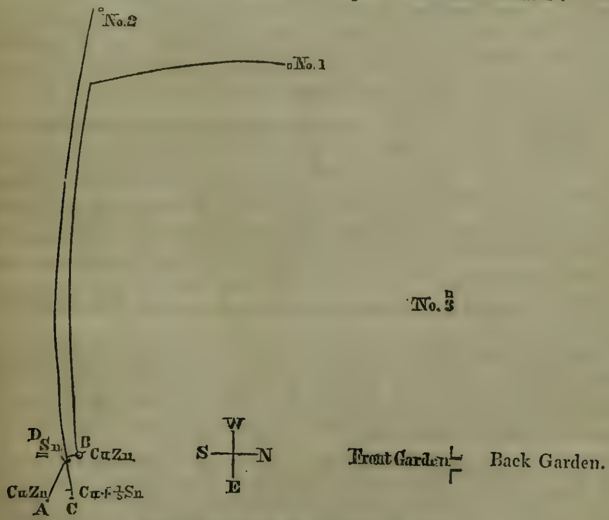
2. The direction and strength of this current depend upon the *time* of the day, the season, the year, &c., and seem to be functions of the azimuth of the straight line joining the centres of the buried plates.

3. The strength of the current seems also to be a function of the *length* of this straight line.

4. There will generally be at least one neutral line in which buried plates will be inactive; this line the author thinks the magnetic meridian of the place will be found to be.

5. As to the *sign* of the current along the *wire*, the author is quite at a loss to account for its very curious changes from one time to another; nor, knowing its sign at any one moment in the *wire*, can he say what is most likely to be its sign at that moment in the *earth*, not having been able to complete a series of chemical experiments begun for that purpose.

Dunsink Garden. Scale $\frac{1}{110}$. Slope to Southward about 4°.



Metals buried at A, B, C, D; April 20, 1857.
Brass at A and B.
Copper + about ⅕ Tin, at C.
Tin at D.

On some Modified Results attending the Decomposition of Bituminous Coals by Heat. By Dr. A. A. Hayes, *United States.*

When bituminous coal is exposed in proper vessels to a gradually increasing temperature, at a certain point decomposition commences and continues, while heavy hydrocarbon vapours, mixed with the vapours of water and salts of ammonia, escape, and may be condensed.

The proportion of permanent gases formed is small in comparison with the weight of the liquids produced, when the decomposition of the coal is carefully regulated.

In the ordinary rapid breaking up of the composition of coal by heat suddenly applied in the manufacture of illuminating gas, the proportion of permanent gases is increased, but the heavy fluid hydrocarbons are also formed. This mode of decomposition is evidently a mixed one, partaking of the characters of a regulated distillation, while at the same moment a more complete destruction of the coal is proceeding in some parts of the mass.

A further decomposition of the fluid products, condensed from either or both of these modes of operating, takes place when we again subject them to the influence of heat; and this well-known fact is the basis on which improvements in the manufacture of illuminating gas have been founded,—a secondary destruction of vapours being effected in appropriate apparatus, heated to a high temperature.

This character, which all the bituminous coals exhibit, of passing into carbon nearly free from vapours only when heavy fluid hydrocarbons are also formed, has, in a chemical view, been the strongest fact adduced in opposition to the generally received opinion that the anthracites and semi-anthracites have resulted from chemical changes of bituminous coal, through the agency of the heat of igneous rocks which have disturbed their beds. The heavy hydrocarbons, represented by ordinary coal-tar, are the most indestructible bodies known; and wherever anthracites exist, we should expect to find near those products of the chemical changes effected in the coal. Such is the delicacy of the balance existing between the elements of the heavy hydrocarbons, that no second distillation of them can be effected; they always undergo decomposition by heat, with the separation of carbon, which, under any known natural conditions, would remain to attest their previous presence.

Considerations of this kind have led me to experiment on the changes which coals undergo by heat, where the influencing conditions were not the same as those usually seen; and the results of extended trials demonstrate that the bituminous coals may be broken up into permanent gases, vapours of water, and ammoniacal salts, while carbon remains as a fixed product.

If we substitute, for the ordinary forms of apparatus used in decomposing coal by heat suddenly applied, any modification of form which compels the gas, as it forms, to escape from the more highly heated part of the mass of coal, through a small opening, or, better, a small eduction-pipe, the heavy hydrocarbons do not form part of the products which escape. Generally the light, nearly colourless oils of the benzole series appear with the aqueous solutions of the ammoniacal salts, while only an accidental quantity of carbon is deposited in the eduction-pipe. The carbon left is more than usually compact and hard; and such coals as ordinarily produce much water, when they form heavy hydrocarbons, afford less than half the usual amount, when thus decomposed, under the influence of the constant presence of an atmosphere of permanent gases.

In following the observations at the earlier stage, it was found that the size of the eduction-tube leading the gas from the hotter part of the mass of coal undergoing changes, exerted a most marked effect on the composition of the products. It was established as a fact, that in an ordinary coal-gas retort, the size of the conduit might be varied so as to allow the tar-like bodies to form, or to prevent their appearance at pleasure.

But a more remarkable result was obtained, when, after having prevented the production of heavy hydrocarbon fluids, the influence of reduced size of tube was studied in its relation to the composition of the gas afforded by a particular kind of coal. To a certain extent, the chemical constitution of the gas formed was found to be under control, and the conclusion reached was, that dissimilar permanent gases may be thus obtained from the same parcel of coal without a modification of temperature.

Any explanation of the change of composition induced in the volatile parts of

bituminous coals under the above-described conditions should not include mechanical pressure, which is no greater than often exists in ordinary cases.

It seems probable that the presence of an atmosphere of nearly permanent gases in the decomposing vessel, and the regular continuous flow of them from the coal, prevent the formation of heavy vapours at the instant of change in the coal. In support of this point, we find the temperature necessary to convert coal into gas without the presence of heavy hydrocarbons much less high than when they are produced.

We may therefore observe the decomposition of coal without the simultaneous formation of tar, and beds of coal may be converted under existing natural conditions to anthracite without secondary products being formed.

On a new Method of administering Chloroform. *By* M. le Baron Heurteloup. (*Communicated by* M. l'Abbé Moigno.)

This method consists in *projecting* the chloroform by means of a simple apparatus composed of a small pair of bellows, to which is adjusted a sort of glass syringe. The latter is a small hollow glass tube having a cork at each end; at the further extremity is fixed a metallic tube of a conical shape terminating in a point, through the other cork passes another metallic tube communicating with the bellows by means of an india-rubber tube. A given quantity of chloroform is introduced into the syringe on a piece of gauze; a slight movement of the bellows drives out the chloroform against the mouth and nose of the patient. In this manner the author can regulate the inhalation of the chloroform, and, moreover, the persons present are not so much affected by its vapours as when it is administered in the ordinary manner.

On illuminating Peat Gas. *By* R. L. Johnson.

The author stated that it is now nearly half a century since a Parliamentary Committee appointed by Government to report on Irish peat named the town of Sligo and the Hill of Howth as the extreme points of a straight line, and Galway and Wicklow Head as the extreme points of another straight line, between which two right lines lay the six-sevenths of all the peat in Ireland, the remaining one-seventh being distributed throughout localities on either side of these lines. Having named the different localities where peat is distributed, the total quantity of which in superficial acres appears to be three millions, Mr. Johnson entered into a detailed description of the mode by which he obtained illuminating gas from common peat or turf, which he produced by the double decomposition of the constituents of the peat. He stated that works for the production of the gas have been recently erected and are in actual operation in two places in Ireland. In the Queen's County and County Westmeath, the gas produced was good, and its cost, as stated to him by a gentleman who was using it, less than 2*s.* the thousand cubic feet. He stated that from one single pound weight of common peat an hour's light may be produced, that its cost being so very small it should ultimately be extensively used throughout Ireland, and that in all peat countries also in its production there was a residual of charcoal equal to one-third of the peat employed.

Notice of Researches on the Assimilation of Nitrogen by Plants. *By* Messrs. Lawes, Gilbert, *and* Pugh.

Whether or not plants can assimilate the free nitrogen of the atmosphere, is in a purely scientific point of view, a question of high interest; and, if answered in the affirmative, will add a striking fact to the history both of nitrogen itself, and of the vegetative functions. A true theory of many agricultural facts and practices requires a definitive solution of this debated point. The earlier writers supposed that the free nitrogen of the air could be taken up by plants. De Saussure and others came to an opposite conclusion; and this latter view has been pretty generally adopted by scientific observers. M. Boussingault in particular, adduced experimental evidence to show, that plants do not assimilate the free nitrogen of the air. But, during the last few years, an extensive and elaborate series of investigations has been made by Mons. G. Ville of Paris, the results of which led him to conclude, that plants sometimes assimilate a considerable amount of free nitrogen. M. Boussingault has followed up the inquiry in various ways, and still maintains the opposite opinion. It is hence highly

desirable that others should undertake the subject; and it was the plan adopted by the authors to this end, and the indications so far obtained, that they now brought before the Section. They described the several methods adopted by M. Boussingault and M. Ville respectively, and then illustrated by drawings their own methods and progress. In all cases their plants grew, in the first instance, in soil and atmosphere destitute of all combined nitrogen, except that contained in the seed sown. To some, however, as their growth seemed to indicate the need, for the sake of comparison, small and known quantities of ammonia (as sulphate), were supplied. Drawings of the progress of the plants showed a very considerable increase of growth where this ammoniacal supply was given. In some of these cases, the plants promised to yield seed, and their height and general development was pretty natural. In other instances, where only the combined nitrogen of the seed sown, and the free nitrogen of the air, were available, the plants remained exceedingly small, and withered before coming to perfection. The quantitative result could not, however, be known, until the growing plants, the soil, and the pots in which they grew, were analysed; when the debtor and creditor account, so to speak, of the nitrogen, could be made up. Collateral researches were briefly described, the object of which was, to throw light on the relation of the gases evolved during the growth of plants, to constituents actually assimilated; and also others, to show whether free nitrogen was a product of the decomposition of organic matters under certain circumstances.

On the Chemical Composition of an ancient Iron Slag found at Lochgoilhead, Argyleshire. By John J. Kyle, *Assistant in Chemistry, Surgeons' Hall, Edinburgh. (Communicated by* Dr. Stevenson Macadam, *F.R.S.E.)*

This paper had reference to a discovery made by the author, during the autumn of 1856, of a quantity of iron scoria or furnace slag, as also portions of charcoal, and other remains indicative of the existence, at some remote period, of an ancient iron work or "Bloomery" on the shores of Loch Goil in Argyleshire. The slag referred to, which the author has subjected to analysis, yielded him the following results:—

Silicic acid	29·60
Alumina	5·60
Lime	2·80
Magnesia	3·72
Protoxide of iron	56·52
Sulphide of calcium	1·00
Loss, with traces of manganese and phosphoric acid	0·76
	100·00

Referring to the large amount of protoxide of iron entering into the composition of the slag, the author stated his belief that the process of manufacture adopted in this bloomery was in all probability that known as the direct or Catalan process, in which the ore is reduced by the action of the fuel, without the intervention of any flux, and giving rise to the formation of a silicate of iron, which from its great fusibility would readily admit of being run off at a comparatively low temperature. It having been long remarked that ancient scoriæ found on elevated positions almost invariably contained a large proportion of iron, whilst those found on less exalted districts had but little of that metal in their composition, it had hence been inferred that the former indicated the more ancient seats of the iron manufacture, as, prior to the introduction of bellows as a means of forcing air into the burning fuel, open and exposed situations would be best adapted for furnace operations, seeing that the natural currents of air could have more ready access to the combustible than in sheltered localities; although even by the adoption of this expedient, the operators of these early times would be unable to command a temperature sufficiently intense to enable them to employ a flux such as lime, with the view of removing the silicic acid of the ore, owing to the difficultly fusible nature of the calcareous silicate thus formed. From the preceding considerations the author drew the inference that the Loch Goil bloomery was one of the most ancient in the kingdom, remarking that in this view he was borne out by the nature of the position where the remains were discovered, it being one which, although at no great elevation, was yet freely exposed to the sudden and high

winds almost constantly sweeping through the glen. In conclusion, he stated that he had as yet been unable to prove the existence of any natural deposits of iron ore in the vicinity of Loch Goil, but intended to examine the locality more fully on an early occasion.

On the Purification of Large Towns by means of Dry Cloacæ. *By* Dr. Lloyd.

On the Atomic Weight of Aluminium. *By* Professor J. W. Mallet, *University of Alabama, United States.*

Some experiments were described by the author which he had made upon metallic aluminium prepared in Paris and in Berlin. The composition of the commercial metal was found to be—

	Paris.	Berlin.
Aluminium	92·969	96·253
Iron	4·882	3·293
Silicon	2·149	454
Sodium	trace	trace
Titanium	trace?	
	100	100

Dissolving the metal in dilute muriatic acid, precipitating with ammonia, weighing the precipitate, and calculating from the results, and from the above composition of the crude metal, the weight of pure alumina yielded by a given weight of pure aluminium was found, and hence the equivalent of the element. The number deduced from one experiment, out of four made, differed so seriously from that given by the other three, that the investigation must be looked upon as still quite incomplete. The apparent cause of the discrepancy was pointed out; namely, the retention by alumina of a small amount of water at even a very high temperature. The importance of a speedy revision of the atomic weight of aluminium was insisted upon, the method by which the number now admitted was obtained being noticed as ill-suited to give an accurate result.

On the Melting-points of Bodies. *By* Dr. Miall.

Notices of Photography. *By* M. l'Abbé Moigno.

The Abbé Moigno presented, in the name of M. Bertsch, 'Microscopic Photographs;' in the name of Mr. Bingham, 'Improved Photographic Copies of Oil Paintings;' and in the name of M. Nièpce de St. Victor, 'A perfectly New Method of exhibiting, by means of Photography, the Phosphorescence and Fluorescence of Bodies.'

There are two methods of rendering evident this new action of light upon bodies submitted to its influence. The first consists in the exposure to light of an engraving which has been kept in a dark place, and which after exposure is placed upon a sheet of photographic paper. After twenty-four hours' contact the engraving leaves its image upon the latter, the black parts of the drawing making a white expression on a dark ground. In this experiment the engraving may be replaced by any other body: wood, paper, ivory, porcelain, &c., all act more or less in the same manner. If the interior of an opake metallic tube closed at one end and lined with paper or card-board, be exposed to the sun for about an hour, and then taken into a dark room, it leaves the impression of its circular orifice on photographic paper; and if after exposure its extremity be closed and sealed up, the interior will preserve its radiating power for a considerable length of time, and will act on photographic paper on being opened.

A drawing made upon paper with fluorescent or phosphorescent substances, such as sulphate of quinine, &c., and exposed to the sun, prints itself on photographic paper in the dark, far better than those parts of the paper which the salt has not touched. A plate of either ordinary glass, or of glass coloured by oxide of uranium, when placed between the drawing which has been exposed to light and the photographic paper, prevents the impression taking place. If the drawing in sulphate of

quinine has not been exposed to light, it produces no effect on the photographic paper. Other substances act as sulphate of quinine.

The second method of rendering palpable this peculiar action of light is as follows:—"I take," says M. Niepce, "a sheet of paper which has been kept for some time in complete darkness; I cover it with a photographic print taken either on glass or paper, and I expose them to the rays of the sun, after which I immediately carry my sheet back into a dark room. Taking off my photographic print, I plunge my sheet of paper into a solution of nitrate of silver; in a very short space of time the image of the print appears upon it. It is only necessary to wash the sheet in water to fix permanently the impression thus obtained. To obtain a more perfect impression, and one, moreover, produced in a still shorter space of time, it is necessary that the sheet of paper be previously impregnated with one of those substances which possess, to a great degree, the faculty of absorbing light. The most efficacious is perhaps a solution of nitrate of urane or tartaric acid. The image obtained by the medium of these substances is of a chestnut colour. To render it black, it may be treated with chloride of gold. The prints thus obtained are *positives*; they resist the destructive action of boiling cyanide of potassium, ammonia, &c.; *aqua regia* alone destroys them. A slight degree of heat accelerates the above phenomena."

The author has experimented with a great number of absorbing substances and with very varied effects. He is still occupied with these interesting researches.

On Three New Electrotype Processes. By M. L'ABBÉ MOIGNO.

The first of these improved processes consisted in the employment of platina wires instead of copper, and of making a skeleton figure resembling roughly the outline of the cast sought to be obtained, by means of which, according to M. Lenoir's process, busts, statues and groups can be produced in full relief by a single operation. The second of these consisted in M. Oudry's process for galvanizing or coppering iron and cast iron to any thickness required without the cyanide bath, with remarks upon its employment in commerce and in the navy. The process was not fully communicated, as it is commercially desirable to keep it a secret; but sufficient was communicated to show that the cyanide bath, which is not only expensive but dangerous, can be dispensed with, and the present system, according to which there was a great waste of material, avoided, although the substance that was placed upon the iron to induce the deposit of the copper was not stated. The process essentially consists in depositing by electricity, copper in a pure state, to any thickness, upon articles of cast, wrought, or rolled iron, zinc and other metals, and alloys of metals, after being coated with one or several coats of a composition in a liquid or semi-liquid state, serving as an isolating and metallizing medium. The author claims also as his invention the application to metallic articles, compositions, paints or varnishes of any kind to act as protective intermediates, before depositing on them the required thickness of copper, by means of the galvanic battery. The last branch of the paper treated of Messrs. Christofe and Bouillet's process for strengthening electrotypes, the principle of which was to leave an opening in the back of the thin electrotype obtained by precipitating, and to put into it various little pieces of brass, which, on being melted with an oxy-hydrogen blast, became diffused all over the interior surface of the copper without injuring it in any way, and thereby imparted to it the strength of cast iron.

On the Choice of Perennial rather than Annual Fertilizers. By Sir JAMES MURRAY, *M.D.*

The author referred in the first place to the writings of Mr. S. Ferguson, in the 'Evening Mail,' relative to the soluble biphosphate of lime, first applied to land near Belfast forty years ago. One of these mere trials, with vitriolized bones, yielded luxuriant crops in June 1808. Long-continued experiments having now convinced him that the soluble biphosphates were in fact *too soluble*, he had turned his attention to some combination in which the principal qualities of the manure might be consolidated, for liberation, little by little, as required by the state of the crops. He laid before the meeting some of the double phosphate of ammonia and magnesia, artificially prepared as a fertilizer, which will remain nearly insoluble, in tanks or on lands; and yet by a light sprinkling of muriatic acid or common salt mixed with light dust, in

water, or sewage, will assume a condition favourable for the young crops to imbibe what they require.

On Coloured Confectionary. By Dr. M'Namara.

The author drew the attention of the Section to the large quantity of highly poisonous colouring matters employed in the manufacture of confectionary. He referred to cases of deaths resulting from this practice. He alluded to the manner in which these substances might be coloured by vegetable colouring materials of a harmless nature, and suggested that a list of such colours should be compiled by parties competent to the task, from which alone confectioners should be permitted to select their colours. He gave a sketch of such a list, and exhibited some beautifully coloured confectionary, in which such colouring matter had been employed. These confections he had for some time in his possession, and their colours did not appear to have faded. In conclusion, he cautioned the public against buying any confectionary in which green or blue colours exist, as such colours are probably produced by poisonous agencies.

On the Effects of Alum in Panification. By W. Odling, *M.B., F.C.S.*

The author maintained that during the process of making fermented bread, in addition to the fermentation of some of the sugar of the wheat into alcohol and carbonic acid, another species of fermentation or change most frequently took place, which consisted in a transformation of the starch into dextrine or sugar, and occurred to the greatest extent in flour that had undergone a damp harvesting, in some cases even to such an extent as to prevent altogether the production of a presentable loaf, save by the use of alum or some such agent. It appeared that alum exerted very little effect upon the necessary fermentation of the sugar into carbonic acid and alcohol, but that it impeded very greatly, or altogether prevented, the conversion of the starch into sugar. It was found that dough having of itself a tendency to undergo this saccharine change, or having the tendency induced by means of an infusion of malt, yielded loaves that were dark-coloured, sodden, sticky, sweet, and uneatable; while the same dough, with the addition of alum, yielded loaves that were white, dry, crumbly, and unobjectionable both as to taste and appearance.

On the Presence of Copper in the Tissues of Plants and Animals. By W. Odling, *M.B., F.C.S.; and* A. Dupré, *Ph.D.*

The authors had made more than 100 examinations by a great variety of processes, and had recognized the presence of copper in nearly every instance. In several specimens of wheat-grain and animal tissue the copper had been estimated. From 100 grains of wheat-ash, the authors had obtained ·023 grain, and from an entire sheep's liver, ·515 grain, of oxide of copper. The process used, was to precipitate the copper eletrolytically on a platinum wire, to dissolve the deposit in nitric acid, and to ignite the residue of the evaporated solution.

On a new Method of forming Ammonio-Iodides of Metals. By the Rev. J. B. Reade, *M.A., F.R.S.*

It is only within the last few years that the attention of chemists has been directed to compounds of metals with iodine and ammonia. The 5th edition of Brande's 'Chemistry,' published in 1841, is silent on the subject. At the Oxford Meeting of the British Association in 1847, Mr. Reade exhibited the ammonio-iodide and periodide of gold, and he has since experimented with other metals.

The common method of forming the ammonio-iodides, is by placing an iodide of the metal in liquor ammoniæ, or in ammoniacal gas, with or without heat. The method which Mr. Reade adopts, is to place the pure metal in direct contact with iodine when dissolved in ammonia.

Some caution is required in forming this solution, but with ordinary care to secure a large excess of iodine, which dissolves teriodide of nitrogen if formed, the explosion of this terrible compound may be avoided.

Solution of Iodine in Ammonia.—Perhaps the best mode of dissolving iodine in ammonia for the purpose in question, is to place about 50 or 60 grains of iodine in an evaporating dish, hold it over the spirit-lamp for a few seconds till it is thoroughly warm

and the vapour arises, and then add a few drops of liquor ammoniæ, which will be immediately charged with a large excess of iodine in solution. This may be poured into a bottle, and more iodine and ammonia added until the requisite supply is obtained.

Ammonio-iodide of Gold.—Gold-leaf when placed in the iodine solution instantly turns black (or purple if the solution be diluted), and immediately dissolves, like sugar in water. If left to evaporate spontaneously in some quantity, we obtain black four-sided prisms of the ammonio-periodide, which readily dissolve in water; and if a very weak solution be exposed for some months to the direct action of the sun's rays, a slight precipitate appears, and a drop or two of the clear solution furnishes a most striking microscopic object, both as to crystalline arrangement and richness of tint, when placed in polarized light.

The application of gentle heat to the ammonio-periodide expels iodine, and leaves white crystals of the ammonio-iodide.

The addition of ammonia to the ammonio-iodides is generally attended with interesting results. In the present case, by adding ammonia to the periodide of gold we obtain a crop of minute six-sided crystals terminated by hexahedral summits, and acted on by polarized light.

If a drop or two of the iodine solution be spread on a slip of glass, and two or three square inches of gold-leaf be dissolved in it, a very slight application of heat will quicken the crystallization and cause it to assume the arborescent form, or if the little forest be not quite satisfactory, a second solution, by means of a drop of water and re-crystallization, will give what is required. The slip of glass must now be held over the spirit-lamp to drive off the iodine, at first slowly, and continued there till the evaporable elements are gone and nothing remains but metallic arborescent gold as a charming microscopic object. It may be protected by Canada balsam, as in the example exhibited. The ammonio-periodide of gold is a very valuable ingredient in the toning bath for photographic pictures. Before adding it to the solution of hyposulphite of soda, or using it as an independent bath, it should be dissolved in water and boiled in a test tube, or an evaporating dish, to drive off any free iodine, and then the quantity added to the bath depends upon the tint required for the picture, which may be brought up to a deep purple.

The solution of iodine in ammonia may also be successfully used in separating the pure metal from gold ore obtained at "the diggings," where the per-centage of gold is very small. In a commercial point of view this solution might be in some cases even more available than mercury, and the iodine could be easily collected and used for further experiments.

Ammonio-iodide of Silver.—Gmelin says of the ammonio-iodide of silver, that "unfused iodide of silver absorbs with evolution of heat 3·6 per cent. of ammonia, and forms a white compound, which on exposure to the air gives off ammonia and turns yellow again."

The phenomena are far more interesting when silver-leaf is added to the ammonia solution of iodine. The metallic silver is immediately dissolved, and when a few drops are placed on a slip of glass beautiful brushes of prismatic crystals shoot out in all directions, which may be mounted as a microscopic object in Canada balsam after the excess of iodine is spontaneously evaporated. Under polarized light the colours of the crystals are brilliant in the extreme.

A few drops of rather strong ammonia added to these crystals of ammonio-iodide of silver on the stage of the microscope, produce a crop of hexagonal and triangular plates, which attain soon after their formation a variety of tints rivalling the reflexions from the facets of the diamond. They must of course be viewed as opake objects, but unfortunately they are not permanent and cannot be preserved in the cabinet. This is also the case with similar crystals of iron similarly formed.

Ammonio-iodide of Mercury.—The phenomena in forming this compound are varied and interesting. Mercury is added to the iodine solution, and after the application of heat and the addition of a little water, a few drops on a slip of glass give bundles of prismatic crystals similar to those of silver, and acted on with the same energy by polarized light. If ammonia be added to these crystals they are immediately covered with tufts of snowy whiteness, and by degrees these are converted into ruby-coloured hexagonal prisms which are permanent.

Ammonio-iodide of Cobalt.—Brande observes that "no precipitate is produced in

solutions of cobalt either by hydriodic acid or iodide of potassium, or by iodic acid or iodate of potassa." The author finds, however, that cobalt yields to the action of the ammonio-iodide solutions after some hours' digestion and a little heat and water. As might be expected, it exhibits very strongly the sympathetic properties of the chloride; for when placed on paper and gently heated, it becomes a brilliant green, which of course vanishes as the paper cools.

The prismatic crystals obtained by evaporation on a slip of glass and mounted in balsam are decidedly acted on by polarized light; but the chief value of this new compound will be found in its properties as a photographic agent.

When used for the purpose of iodizing collodion, it certainly produces richness of detail in those parts of the picture where iodide of potassium often fails, and it is also exceedingly sensitive to the action of light when ordinary attempts would be fruitless. Photographic chemists may therefore profitably turn their attention to this compound.

Ammonio-iodide of Titanium.—As titanium, which resists every direct method of attack in the laboratory, yields after a period of digestion in the iodine solution, it is probable that other of the scarcer metals, which are with difficulty reduced by the ordinary methods, might be exhibited in the form of ammonio-iodides, and thus throw additional light on their respective equivalents.

The crystals of ammonio-iodide of titanium which Mr. Reade obtained, were from a pure specimen of the metal obtained by Mr. Waterhouse, of Halifax, from the slag of the neighbouring iron furnaces at Low Moor.

Ammonio-iodide of Aluminium.—In forming this compound, Mr. Reade used not the pure metal, but alumina only, precipitated in the usual way. After allowing the alumina to digest for some time in the iodine solution, the whole was boiled in a little water, which dissolved the new compound, and upon evaporation and the proper measure of heat to volatilize the excess of iodine and ammonia, a white semi-metallic substance remained, as in the case of silver. It is soluble in dilute hydrochloric acid, and yields a blue precipitate on the addition of yellow prussiate of potash. Whether any use can be made of this process towards obtaining the pure metal, is a problem for practical men.

On Fused Wrought Iron.

By E. Riley, *F.C.S* (*Communicated by* Dr. Odling.)

The author had succeeded in running down, with great facility, several ounces of best cable bolt-iron into buttons of metal, which presented on fracture a beautiful lamellar structure, and worked extremely well at a low heat; but which, after having been exposed to a welding heat, was altogether useless, from its property of cracking or crumbling.

On the Nutritive Properties of the Potato, when properly manipulated, as compared with Wheat, &c. By Jasper W. Rogers, *C.E.*

The object of the writer was to introduce the use of the potato for the manufacture of flour and meal analogous to flour and meal of wheat and oats, and thus to preserve the potato in a state equally fit for the food of man. It was an error to imagine the potato had not the same elements of nutrition as *wheat and oats*. The nutritive properties of the potato, when deprived of its average quantum of water, which might be stated at 75 per cent., were as follow:—

Of starch	84·077 per cent.
„ gluten	14·818 „
„ oil	1·104 „

Whilst the nutritive properties of wheat are—

Of starch	78·199 per cent.
„ gluten	17·536 „
„ oil	4·255 „

Why then should the potato be used merely boiled or baked as a garden vegetable, whilst by proper manipulation it might be converted into a material for producing meal and flour nearly, if not fully, equal to wheat, and of a nature also, that resists the usual action of climate and decay, as had been abundantly proved by its transmission to the tropics, as well as by tests made by the writer under the orders of Government in producing several descriptions of food from potatoes at the South Dublin Union?

But the proper manipulation of the potato was the more imperative and essential, from the fact of the greatly increased quantity of food which it yields as compared with wheat. An acre of land planted with potatoes, will, when the watery portion is extracted, produce, of dry matter or meal, similar in appearance to wheaten meal, about 4076 lbs.; whilst an acre of wheat will produce but about 1055 lbs. Thus the quantity of food from the potato, nearly analogous to food from wheat, is nearly four times that from wheat.

Samples of the several preparations of meal and flour of potato were exhibited; and the process of manufacture was stated to be so simple as to be within reach of farmers and householders generally, by using the usual appliances of the dairy, &c.

On some of the Medicinal and Chemical Properties of Carbonized Peat Moss *By* JASPER W. ROGERS, *C.E.*

Peat possesses in itself, and in the water combined with it, great anti-putrescent powers. Human bodies have been frequently found in peat mosses in a state of preservation scarcely inferior to that of an Egyptian mummy. The analyses of peat moss discover substances not to be found in wood, amongst others "paraffine," closely analogous to spermaceti. The absorptive power of peat moss, properly carbonized, was found by measure as follows:—

100 volumes of Ammoniacal gas.
60 „ „ Sulphuretted hydrogen.
40 „ „ Carbonic acid gas.

The author states, that experiments as to the effects to be obtained by the action of "carbonized peat," used medicinally, had been made by competent medical men, and that in dyspepsia, and all diseases of the stomach and chest, the effect of carbonized peat moss, exhibited internally, had been found specially advantageous. He proposes an explanation of this effect on the known anti-putrescent quality of peat, and concludes that if it be true, it can scarcely be doubted that in "carbonized peat is to be found a remedy for cholera. It is an *anti-putrescent* and a *tonic*, combined with *an absorbent* power, which has no known equal."

Ozone Observations. *By* Professor W. B. ROGERS.

On a Process for the Determination of the Nitrates in Plants. *By* Professor W. K. SULLIVAN, *Ph.D., M.R.I.A.*

The author pointed out the great importance of finding a process for the purpose, because in determining the amount of nitogen in plants by the usual processes, a part of the nitrogen of the nitric acid is included in the result, and consequently the true amount of assimilable azotic proximate principles cannot be deduced from ultimate analysis, if nitrates be present. The chief feature of the process is the use of sulphovinate of silver to precipitate the vegetable acids; the silver salts of which are insoluble in absolute alcohol, while the nitrate of silver is soluble. He also pointed out a method of separating lactic and acetic acids from one another when present.

On the Presence of several Acids of the Series $C^n H^n O^4$ *among the Products of the Distillation of Peat.* *By* Professor W. K. SULLIVAN, *Ph.D., M.R.I.A.*

Professor Snllivan stated, that he first observed the presence of butyric acid in the acetic acid prepared from peat, about five or six years ago, but had not an opportunity of examining the subject further until recently, when he became possessed of a large quantity of raw products of peat, which he hoped gradually to investigate. The process of separating the acids, and the results of the analyses of some of the compounds of each, were described. The salt of baryta, which was obtained with butyric acid, contained four equivalents of water, and therefore corresponded with one of Chancel's salts. The tendency of butyrate of baryta to crystallize in the anhydrous form was remarked, and the great difficulty of obtaining the hydrated salts, which accounts for Lerch having always obtained that salt as an anhydrous compound. The formation of a considerable amount of cyanide of ammonium, by the destructive distillation of peat, was also established.

Remarks on the Solubility of Salts at high temperatures, and on the action of Saline Solutions on Silicates under the influence of Heat and Pressure. By Professor W. K. SULLIVAN, *Ph.D., M.R.I.A.*

The author observed, that crystallized gypsum heated with water in a sealed tube to a temperature of 150° Cent. lost part of its water, and formed the hydrate $2(CaO\ SO^3)$, HO; when heated for several hours at a temperature of 200° C. it was completely dehydrated. Several of the zeolites, heated under similar circumstances, were also dehydrated, but this required a much higher temperature, and a much longer exposure to the heat than the dehydration of the gypsum. Some experiments upon the solubility of salts at high temperatures were also mentioned, and a suggestion made as to the probability that there exists for each salt a temperature of absolute insolubility, unless it was a compound decomposable at a much lower degree. In connexion with this subject, the author confirmed the interesting observation of M. Cousté, of the total insolubility of sulphate of lime at a temperature of about 150° C. The author stated that he was still engaged with experiments upon this subject.

On the Composition of Norwegian Apatite. By Professor VOELCKER, *F.C.S.*

The author stated that all the specimens of apatite which he obtained from Krageröe in Norway, were perfectly free from fluorine and contained variable quantities of chloride of calcium.

In some specimens he found as little as 1·61 to 1·71 per cent. of chloride of calcium, in others as much as 6·41 to 6·70.

These specimens were obtained from the same block of crystalline apatite. The following analyses express the composition of several specimens of this Norwegian apatite:—

	I. Red.	II. Apatite.
Hygroscopic water	43	·43
Water of combination	40	·40
Phosphoric acid	41·88	41·74
Lime	53·45	54·12
Chloride of calcium	1·61	1·61
Magnesia	....	·20
Phosphate of iron and alumina	166	·45
Insoluble siliceous matter	1·24	·97
Alkalies	....	·30
	99·67	100·22

White Apatite.

	I.	II.
Hygroscopic water	·19	·298
Water of combination	·23	·198
Phosphoric acid	41·25	42·28
Lime	50·62	53·35
Chloride of calcium	6·41	2·16
Oxide of iron	·29	·92
Alumina	·38	
Magnesia	...	
Potash	·04	
Soda	·13	
Insoluble siliceous matter	·82	·99
	100·36	100·196

All the samples of apatite were perfectly free from carbonates. After uniting the phosphoric acid with lime to tribasic phosphate, and with chlorine, there remains over in each analysis an appreciable quantity of lime, which is neither united with carbonic acid nor with fluorine. At any rate, the author's results show that the ordinary formula for apatite cannot be applied to the apatite from Krageröe, which, as has been stated, is distinguished by the entire absence of fluorine, and a very small proportion of chlorine in some specimens.

On the Methods of Analysing the Superphosphates. *By* Professor VOELCKER, *F.C.S.*

In this paper Dr. Voelcker reviewed the different methods of analysing superphosphate, and directed attention to the fact that the biphosphate of lime in commercial superphosphates is decomposed when the latter are boiled out at once with water, in consequence of which the amount of soluble phosphate is always obtained too low if boiling water is employed for extraction.

He showed likewise that the amount of organic matter and ammoniacal salts in superphosphate cannot be determined as usually done by burning, inasmuch as sulphuric acid is thereby driven out, and the per-centage of organic matter obtained too high.

Superphosphates often contain common salt in considerable quantities; in determining the alkaline salts, the common salt is obtained as sulphate of soda, and has to be stated in the results of chloride of sodium. He next pointed out the variable composition of the precipitated phosphates, and recommended in accurate analyses the method of Wöhler for determining the composition of the phosphates.

Allusion having been made to the irrational manner of stating the results of analysis, Dr. Voelcker described his own plan of analysing superphosphate, of which the following is a brief abstract.

Water and nitrogen are determined as usual. 30 to 35 grains of superphosphate are exhausted three or four times with two ounces of distilled water each time, and then boiled out with sufficient water to obtain an excess of gypsum in solution. The insoluble portion is collected in a weighed filter, dried, weighed, and then burned. The ash is then dissolved in HCl, the solution precipitated with ammonia, and the filtrate from insoluble phosphates with oxalate of ammonia. The portion dissolved in water is concentrated with the addition of some HCl to prevent phosphates falling down, the soluble phosphates are then thrown down with ammonia, the filtrate from phosphates is precipitated with oxalate of ammonia, and the filtrate from lime evaporated for alkaline salts. In accurate analysis the phosphates have to be analysed.

On the Proportion of Organic Phosphorus in Legumine. *By* Professor VOELCKER, *F.C.S.*

The presence of phosphorus in legumine, contained in it in organic combination and not in the form of phosphates, was shown by the author by deflagrating a mixture of legumine with carbonate of soda and nitre, dissolving the white residue in dilute hydrochloric acid, and precipitating the sulphuric acid with BaCl, removing the excess of BaO by pure sulphuric acid, adding to filtrate from BaO, SO^3 ammonia to throw down any phosphates present, evaporating to small bulk, and precipitating finally phosphoric acid with ammoniacal sulphate of magnesia.

In this way the following results were obtained:—

1. *Legumine from green peas.*

Per-centage of sulphur	·870
,, ,, ,, phosphorus	1·383
,, ,, ,, ash	1·100

2. *Legumine from green peas thrown down with very little* $\bar{A}$.

Per-centage of sulphur	·571
,, ,, ,, phosphorus	1·88

3. *Legumine from green peas precipitated with excess of* $\bar{A}$.

Per-centage of sulphur	·851
,, ,, ,, phosphorus	2·180

4. *Legumine from white peas.*

Per-centage of phosphorus	1·52
,, ,, ,, ash	1·45

5. *Legumine from white French beans.*

Per-centage of sulphur	·59
,, ,, ,, phosphorus	1·78
,, ,, ,, ash	·71

On the Preservation of Albuminized Collodion Plates. *By* W. SYKES WARD, *F.C.S.*

Having made numerous experiments on the application of albuminized collodion according to Taupenot's process, in comparison with collodion washed and covered with gelatine, according to the process published by Dr. Hill Norris and others, the author found the albuminized collodion process to give better results in all respects, excepting that of deteriorating by keeping. He also found that plates prepared by Taupenot's process were affected by the wood of the dark slide, especially in some instances in which he employed unvarnished cedar wood.

In the hope of combining the advantages of both processes, he poured on the plates prepared in accordance with Taupenot's process, and whilst yet wet, various solutions of gelatine and metagelatine, and found that these had the desired effect of enabling him to keep the sensitized plates without deterioration at least four times as long as he could, under similar circumstances, keep the plates not so protected.

The additional coating of metagelatine also gives a clearness, brilliancy, and transparency to the negative which is seldom obtained by the ordinary process. The coating of metagelatine is applied after the sensitized plate has been carefully washed, and may be dried by heat, or in the ordinary manner.

The following is the formula preferred:—

Dry metagelatine	10 grains.
Lump sugar	10 ,,
Glacial acetic acid	2 minims.
Water	1 ounce.

On the Processes for the Detection of Fluorine. *By* Professor G. WILSON, *M.D., F.R.S.E., F.C.S.*

The author made an oral communication on M. Nicklès' recent observations on the etching of glass as produced by the vapour of fuming sulphuric acid at a high temperature, and disputed the validity of Nicklès' conclusion, that his results prove the inapplicability of glass to the detection of fluorine in the form of hydrofluoric acid. He also drew attention to the impossibility of detecting minute traces of this acid, if quartz, as proposed by Nicklès, was substituted for glass as the material to be etched, and stated his intention of publishing at length his investigations on the relative suitability of glass and quartz for the detection of fluorine.

On the Time required by Compounds for Decomposition. *By* Dr. T. WOODS.

The object of this paper was to prove that all compounds require a certain length of time in which, under similar circumstances, they can be decomposed; that this *time* is invariable in amount, *definite* and *specific.* It was first shown experimentally that different compounds require different "*times*" in which to decompose. This was done by making a galvanic pair, one end of which was zinc in sulphuric acid, the other end, in a porous cell, platina in the compound to be decomposed. When the metals are joined externally, a galvanometer being included in the circuit, the needle shows the amount of electricity in circulation, and consequently the rapidity with which the zinc is being dissolved, and therefore the "time" in which the decomposition of the compound is going on.

By successively using different compounds, the time for the decomposition of each was seen, and for the same compound always to be the same under like circumstances. It was also shown that the length of time each compound requires for decomposition was proportional to the amount of heat absorbed by the decomposition; the more heat absorbed the longer it required to absorb it; so that the interesting fact was proved, that all compounds require the same length of time to absorb the same quantity of heat in decomposing. It was shown that the galvanometer in this arrangement acted the part of a thermometer of chemical action, as the needle varied exactly with the amount of heat absorbed in a given time.

The paper urged the importance of attention being paid to thermo-chemistry, and claimed the precedence of all others on the subject it treated of, as the "time" of action

in chemical changes had not before been noticed. It concluded by expressing a doubt if electricity and heat could be the same agent, or modification of it, as equivalents of substances always produce, in combining, the same amount of electricity, but very different amounts of heat.

GEOLOGY.

Notice of the occurrence of a Boulder of Granite in the White Chalk of the South-east of England. By Robert Godwin-Austen, *F.R.S.*

The author described first the threefold division of the cretaceous series of the South-east of England; the extent of the area occupied by each division, and the conditions of accumulation thus severally implied—that, commencing from shallow water, each shows more extended boundary lines, and increasing depth.

1. Littoral shingle of Lower greensand or Neocomian group at Farringdon; deepest deposits in Neocomian clays, with Bivalves in normal position, not exceeding ten fathoms.

2. Gault had its deep beds over South-east parts of England, its littoral ones in the West, as in the Halden-sands.

3. The area of the white chalk ranged as far North as the North of Ireland, and from the coast of Scotland to the area of the Baltic, and thence occupied a broad zone over North Germany. In Western Europe the conditions under which the white chalk was accumulated were remarkably uniform; for the whole of the Anglo-French basin (Seine), 800 feet may be taken as its average thickness, the whole a deep-water accumulation.

Rolled shingle and fragments of extraneous rocks have been found in the chalk, and are to be seen in several collections; they are all of crystalline, mostly granitic rocks, and their size is not considerable; yet in every case they are beyond the moving power indicated by the white chalk.

Modes of transfer of marginal materials into great depths are,—

1. By floating sea-weeds. Illustrations of this are to be seen on most coasts, and evidences of it may be detected in most of the older sedimentary deposits.

2. By floating ice.

Description of the Croydon Granite Boulder.—Form, size, and weight such that it could only have been moved by ice; other materials associated with it, such as rounded pebbles of other crystalline rocks and siliceous sand. Such an association of materials sinking in one place, shows that they were held together in the act of sinking, as also when they sank into the fine calcareous mud of the chalk sea-bed.

The author abstained from entering upon a description of the rocks found associated with the Croydon boulder, but stated that such an assemblage existed only in the Scandinavian and other northern regions.

The inferences to be derived from the foregoing considerations have a very interesting bearing on the physical geography of the North European area, at the period of the greatest expansion of the Cretaceous sea. There were regions of the globe then, as now, where coast-ice was periodically formed, was broken up and dispersed; these regions lay to the north of the area of the white chalk of West Europe, and the white chalk ocean extended continuously up to such latitudes.

Why, if ice was the transporting agent, such materials are not more common, was explained with reference to the present course taken by the icebergs and ice-floes of the Atlantic.

During the Drift period of the Pliocene division of geological history, the set of the liberated ice was more eastward, and was dependent on considerations which are well understood and can be made available for every geological period.

On Carboniferous Limestone Fossils from the County of Limerick, collected by the Geological Survey. By W. H. Baily, *F.G.S.*

The author in this communication gave a brief notice of an extensive collection of fossils recently made by the Geological Survey in the neighbourhood of Askeaton

county of Limerick, which, from its containing several new forms, and the fine state of preservation of many of the specimens, presented points of structure and other peculiarities not before described. The fauna of the carboniferous limestone period, which is usually one of the richest in zoophytes, in this collection is represented only by a small proportion, principally belonging to the division *Zoantharia tabulata* of Prof. Milne-Edwards, amongst which are the genera *Michelinea* and *Chætites*, with the characteristic and extensively distributed coral *Amplexus coralloides*. The Echinodermata, which are most familiar to us in a fossil state, in this collection belong almost entirely to one division of crinoids, the Melocrinidæ, consisting of numerous detached bodies, principally of *Platycrinus* and *Actinocrinus*, genera almost exclusively confined to this formation. Remains of animals of the class Bryozoa or Polyzoa, now included with the Mollusca, are well exhibited by various forms, principally belonging to the family Reteporidæ, amongst which are fine specimens of the well-known form *Fenestella membranacea* of Prof. Phillips. Of the Brachiopoda, the family Terebratulidæ are represented by but one species, the *Terebratula hastata*, of which there is a numerous and fine series. Of the Spiriferidæ, there are several characteristic species, together with the *Athyris Roissyi*, a singular and rare form belonging to this family, in which the lines of growth are developed into expansions, giving it a fringed appearance. Of the family Rhynchonellidæ, are the common forms of *Rhynchonella pugnus* and *pleurodon*. The Orthidæ are represented by the well-known *Orthis resupinata*, and the very rare species *Orthis radialis*, and other well-known forms. Also numerous examples of several characteristic and some rare species of the family Productidæ are found, including *Productus aculeatus*; and a new species. Of the genus *Chonetes* there are several interesting and rare varieties, including *C. variolata* (D'Orb.) and *C papilionacea*. The Conchifera, or Lamellibranchiata, form a fine series, containing several new forms, amongst them being several species of the genera *Aviculopecten* and *Pteronites* (M'Coy), shells having an oblique axis like most of the so-called Pectens of the coal-measures. Of the singular shell called *Conocardium Hibernicum* (Pleurorhynchus of Prof. Phillips) several instructive specimens were collected, showing the expanded keel and siphonal tube, which in some species is still more extended, being probably analogous (as suggested by Mr. S. P. Woodward in his 'Manual of the Mollusca') to the soft, elongated siphons of a remarkable group of cockles inhabiting the inland salt seas, Aral and Caspian, burrowing in mud; also a second species, of which several specimens were collected, some of them attaining a larger size than the *C. Hibernicum*, being remarkably perfect, and having a long siphonal tube, which Prof. De Koninck agreed with the author in considering an undescribed form. He proposed, therefore, to dedicate this magnificent species to that distinguished palæontologist under the name of *Conocardium Koninckii*. There are several species of the genus *Cardiomorpha*, one of which, *C. Koninckii*, is new to Britain, and another, a new species, of large dimensions. The Gasteropoda, or univalve shells, are also numerously represented by many genera and species, including a new species of *Macrocheilus*, and other undescribed forms. Of the Nucleobranchiata, believed to be allied to the floating shells of the present day, this collection contains several species of Bellerophon and *Porcellia Puzo*, a discoidal form of great rarity. The highest order of Mollusca, and most important geologically, are those of the Cephalopoda, which are here remarkable for size and rarity of form, all belonging to the order Tetrabranchiata. The Nautilidæ contained many large and fine specimens, some of them being new species. Of the Orthoceratidæ, specimens were collected of *Orthoceras Muensterianum*, fine examples of *O. dactyliophorum*, and the peculiar formsof *Gomphoceras* (*Poterioceras*) *fusiforme* and *Cyrtoceras Verneuilanum*; also of the Goniatites, a division of the Ammonitidæ, several species, including *G. crenistria* and *fasciculatus*, alluded to as contained in this collection, some of them showing external markings and others being new forms.

On a New Fossil Fern from the Coal-Measures near Glin, County Limerick. By W. H. Baily, *F.G.S.*

The fossil plant alluded to by the author, and of which an enlarged representation was given, was collected by Mr. G. Henry Kinahan, of the Geological Survey, from the black shale above the coal townland of Ballygiltenan Lower, county of Limerick, associated with ordinary coal plants. It appeared to be the central portion of a frond,

with about twenty alternating pinnules, which are apparently covered by thecæ, or cases of the reproductive germs, presenting an appearance somewhat resembling rows of small flowers. The unique character of this singular plant, possessing, as it does, a form so totally unlike any recent or fossil plant, combined with the rare circumstance in fossil ferns of the carboniferous period, that of bearing organs of fructification, which here appear to be so fully developed, renders it of great interest, and may possibly constitute it a new generic form.

On the Drift of West Galway and the Eastern parts of Mayo. *By* J. Birmingham, *of Millbrook, County Galway.*

The author sets out by alluding to the interest and importance of the Irish driftsi general, which are well developed in the district to which his paper refers. They differ from the drifts of many other countries by containing no fossiliferous evidence of their comparative date: and, to account for the absence of shells or any traces of boring molluscs in their materials, the author suggests that the remains of those great drifts, which are now exposed, never formed the surface of the former sea-bottom, but were probably situated at a depth to which no shell-fish ever reached. He divides the drift of his district into three principal divisions; namely,—

1. The Clay Drift, from a point between the south-east and the west, forming cliffs on the north, east, and south shores of Galway Bay.

2. The Great Boulder Drift, from a point between the north and the west, overlying the former.

3. The Escar Drift, forming the chains of gravel hills in the interior of the country, from the south-west.

The direction and sequence of those drifts are inferred from their mineralogical characters and relative positions. The perfect round forms of the Escar Hills, and the complete curves that their beds or layers generally exhibit in any stratified section, not only prove their subsequency to the other drifts, but show that their emergence from the waves, at which time they must have received their present contour, did not take place during any glacial period; for if icebergs had been moving about, and grooving the rock bottom of the shallowing sea, the Escars would scarcely have escaped their action, which would be recognized in the tabulation of their summits, or other significant appearances. The long ranges of those gravel hills may show the resultants of currents that had been subdivided from the main stream, and met again at large angles beyond the limits of opposing hills.

He refers to a fact which he considers worthy of note, from being at variance, as he believes it to be, with recognized theory. He often observed that in the Escar drift, the coarser gravel and boulders betray a tendency to arrange themselves in the upper parts of the mass; and he has remarked the same phenomenon in the shoal beds periodically formed by river floods.

He maintains that it is to the power of moving water, and not either to land glaciers or floating ice, that the great boulder drift of his district is also to be attributed. The fact of large boulders being found on the sides and summits of hills, which they must have ascended, sufficiently refutes the land-ice hypothesis; and the floating-ice theory is rendered improbable by the appearance of a regular increase in number, as well as in size and angularity, of the erratic blocks as they are followed towards their source. Their decrease in number, according to their remoteness from their parent rocks, might, indeed, be accounted for on glacial principles, but not so easily their decrease in size; for though the ice-raft may waste away by degrees, and its powers of buoyancy become less, still this must be thought to affect the total quantity, rather than the individual parts of the load that it bears. As its cliffs succumb in its progress through the warm sea-waves, its burden may gradually be reduced; but there is no reason why the largest masses should not be found among the mixed materials which are still carried on its contracting area. If ice, therefore, were the transporting cause of this drift, we should expect to see, scattered over the land, even a few large boulders derived from distant localities; but those are never found so situated; they must be looked for near their source. The clay drift is in some places stratified, and in others amorphous; and it presents no phenomena which, in the author's opinion, oblige us to have recourse to the agency of ice to account for its formation, while its southerly

origin is directly opposed to such a hypothesis. Still the object of the author is not to dispute the existence of a glacial period in his district, but simply to state his opinion that the conditions which the drifts exhibit must be ascribed to the effect of moving water, and not of ice.

He alludes to Agassiz, as the first who applied the ice theory to the drift phenomena of the British Islands, and remarks, that it may be with the geologist as with the painter or the musician, in whose works, though they speak the universal language of genius, a national accent may still be noticed; and the ice or water theories may, to a great extent, owe their origin to the physical circumstances of the native countries of their proposers. An inhabitant of Switzerland, who has been accustomed to observe the vast powers of the glaciers grinding away the sides of mountains, scooping out their bed in the granite rock, and carrying the fragments of fallen peaks on the crests of their solid waves, must see that ice is indeed a great agent in geological phenomena; and, on the other hand, to a native of our western isles, who has been viewing the Atlantic from his childhood, and has seen cliffs pulled down, and the huge masses of their debris tossed about by the surge, the force of water will be considered unsurpassed. One as correctly as the other might found a theory of limited applicability on the great power he had been used to contemplate, but they would be equally wrong in giving it too great a generalization; and the author hopes that, in his own opinions, he has not been unduly influenced by local associations.

He thinks that the general contour of the country shows the existence of great denuding action from the east at a period anterior to the drifts; and the rise of outcropping strata is generally towards the lowlands, proving them to be valleys of denudation, where the upheaval and disturbance of the limestone beds rendered them liable to be carried away. Looking south from Galway Bay, a grand illustration of this phenomenon may be seen, where the inclined beach terraces of ancient seas ascend the Burren Hills like stairs of giants; but the remark does not apply to the mountains west of Loch Mask and Loch Corrib.

On certain Alterations of Level on the Sea Coast of part of the County of Waterford, and the cause thereof. By Dr. Clarke.

The author described the elevation of an ancient sea-beach on the coast of the County of Waterford, extending about two and a quarter miles, and reaching at one part an elevation of 60 feet. The shells found in the upraised beach were exclusively those of *Cardium edule*; the elevation is believed by the author to be of later date than any of the other pleistocene deposits of Ireland. The circumstances attending the formation of trap-rock at Newton Head were noticed as bearing on this phenomenon, the elevation of the beach being apparently dependent on and due to the igneous agency which raised the dyke.

On the Geology of the Neighbourhood of Tralee. By F. J. Foot, *Geological Survey.*

This paper is descriptive of a section north and south, from Bird Island on the south shore of the mouth of the Shannon to the village of Castlemaine.

The rocks seen in this section are given in a descending series, the uppermost being the coal-measure shales, consisting of thick beds of black shale, more or less fossiliferous, alternating with beds of olive-coloured grits, containing fragments of plants.

The rocks under these are those of the carboniferous limestone, which may be divided into three parts, *upper*, *middle*, and *lower*.

The upper limestone in this district varies from a light grey compact to a dark grey crystalline limestone, abounding in fossils.

The middle portion is a thin bed, only a few feet thick, being a shaly impure limestone, representing the calp.

The lower member is chiefly a light gray hard compact rock, abounding in fossils.

The thickness of the limestone is very difficult to ascertain, partly because the limestone is often very thick-bedded, and partly that the great amount of drift in the

district prevents one getting a good section. The lines of stratification are also often much effaced by joints, cleavage, and weathering of the surface. Under the limestone comes the carboniferous slate, consisting of black shale, brown grits, and some calcareous bands, full of fossils, the thickness being about 500 feet. Next comes the yellow sandstone of Dr. Griffith, consisting of yellowish grit and shales, varying from 500 to 1000 feet in thickness. The former is the thickness at the *Slieve-Mish* mountains near Tralee; the latter that near Bird Island. Here I discovered a thin bed full of plants, all branching and some having a cellular structure; there are some leaves that look like those of *Cyclopteris Hibernica.*

Below the yellow sandstone comes a considerable thickness of red sandstones and slates, amounting at Slieve-mish to about 800 feet; from this they pass downward into a conglomerate. A remarkable point about this conglomerate is the manner in which it varies both in thickness and character. Its thickness where it is shown on the line of section, is about 80 feet, and it consists of large and small rounded pebbles of quartz, jasper, and hornstone, in a base of red sand; while about one mile and a half further west (on the south side of the anticlinal of the Slieve-mish range, where the beds are thrown down by a fault), it is more than 200 feet thick, and consists of large angular fragments of gneiss, mica-schist, grey grit, trap ashes, &c., thinning out on the northern slope to about 50 feet.

This conglomerate is the lowest rock seen in this section, but it must not be confounded with that which is now considered as the base of the carboniferous rocks in this district, and which is several hundred feet below it, and lies unconformably on the Silurians.

On the Relations of the Rocks at or below the base of the Carboniferous Series of Ireland. By Sir RICHARD GRIFFITH, *Bart., LL.D., M.R.I.A., F.G.S.*

The author stated that he had found great difficulty, when preparing the several editions of his Geological map of Ireland, in deciding on the class to which certain rocks characterized by brown and reddish-brown grits and conglomerates ought to be assigned.

These rocks occur in three districts in the north; viz. one in the neighbourhood of Pomeroy and Omagh, in the counties of Fermanagh and Tyrone, one forming the Curlew mountains in Sligo and Mayo, one forming the Croaghmoyle mountains and neighbourhood in Mayo, and one extensive district in the south occupying large portions of the counties of Cork and Kerry.

The author then referred to his paper read at the Cork meeting of the British Association for the Advancement of Science, from which it appeared that he was then inclined to connect the conformable brownish-red sandstones and conglomerates with the Silurian system.

The author next referred to his paper read to the Belfast meeting of the Association on the yellow sandstone of the north shore of Mayo, and to the advice tendered to him by Sir H. De la Beche and Mr. Jukes, with reference to the omission on his map of the so-called Old Red Sandstone district, as the red rocks appeared to them to be all carboniferous, an opinion confirmed by the subsequent discovery of *Sigillaria* and *Stigmaria ficoides* within the area, as also in similar rocks at MacSwyne's Bay in Donegal, a very large specimen from which locality is preserved in the court-yard of the Royal Dublin Society.

It appears therefore that these supposed Old Red Sandstone rocks of the North are undoubtedly carboniferous; but it is yet doubtful to what series the red rocks below lying unconformably to them may belong.

The author then mentioned the limits of the true Old Red Sandstone of the South, from the east to the west side of the island, reposing on other red and purple rocks, which in the Dingle district become distinctly unconformable to them, while the red and purple rocks themselves repose conformably on fossiliferous Silurian rocks.

He then described the grounds on which he based his division of yellow sandstone, principally from the occurrence of plants subsequently found by Professor Haughton, Mr. Jukes and others, to extend still lower down into the red rocks; and stated, that as he considered the plants to be the proof of the yellow sandstone being of carboniferous age, he was not prepared to deny the inference that the whole of the fish-beds of

Scotland, and the similar rocks of Glamorganshire and South Wales, might belong to the carboniferous system.

He estimated the mean thickness of the true Old Red Sandstone of the South of Ireland at about 3000 feet, including 800 feet of yellow sandstone.

The author then described an east and west section across Ireland from Blackstairs mountain in the county of Wexford to the extremity of the Dingle promontory in the county of Kerry, and afterwards entered into some details as to the structure of the Dingle district and that round Killarney and Glengariff. He referred more particularly to the great difficulty which arose from the fact that the red and green rocks (for which Mr. Jukes had proposed the term 'Glengariff grits,' a term which had his entire concurrence) were conformable to the Silurian rocks of the Dingle district, while the Old Red Sandstone reposed unconformably on both; on the other hand, in the country south of Dingle Bay, it should be mentioned these same Glengariff grits passed insensibly up into the Old Red Sandstone; and no want of conformity could be found in any part of the series, from the Glengariff grits as far up as the coal-measures; and the author exhibited a north and south section through the Dingle promontory to the valley of Kenmare, illustrative of his views. He then pointed out the analogy between the Glengariff grits and the brownish-red grits of the three districts in the north of Ireland already alluded to, referring to numerous sections which he had formerly prepared.

The author thought, on the whole, from the occurrence of similar felstones and ashes in the Silurian rocks and the Glengariff grits, and the facts stated above, that there was a double probability in favour of those rocks being of Silurian rather than of Devonian age, or at all events that he was justified in the classification which he had made on his map, and in distinguishing these rocks by separate letters and colours.

Notes from the Barbary Coast, with Fossils. *By* G. F. Habershon. (*Communicated by* Dr. Gladstone.)

In this communication there were described the promontory of sandstone stretching into the Atlantic, on which the town of Mogador is built; two islands, likewise of sandstone, one of which contains a remarkable central depression; the sand-hills, and the barren sandy plain, which extends some 20 miles by 5 or 6 inland; and the Iheb-el-Hadeed, or "Mountains of the Iron," a day's journey to the north of Mogador. There is a universal tradition that the plain was once luxuriant with vegetation, but had been gradually covered with sand. This could not have been blown from any desert, as the plain is surrounded on all sides by fertile regions, except that open to the sea. That the land is sinking, is rendered probable by the very low position of the town of Mogador, of a palace built long since by one of the emperors of Morocco, and of a circular fort erected by the Portuguese on the shore and now in ruins, and especially by the fact that it was the custom of the Moors in former times to drive their cattle to feed on the larger island, by a path which is now covered at low tide by about 10 feet of water.

About half a mile from the northern gate of Mogador is a sand-hill, in which Mr. Habershon had seen what appeared the stems, branches, and twigs of many trees, but all converted into sand and hollow. Dr. Gladstone, who had suggested the propriety of bringing over some of these fossils, described the specimens accompanying the paper as branching irregular tubes of carbonate of lime, on the outside of which sea-sand of a very heterogeneous character was cemented by crystals of the carbonate. These specimens varied from half an inch to five inches in diameter; and though he had formed several theories as to their origin and nature, not one of these seemed to meet every point of the case. The communication was further illustrated by specimens of sandstone from Mogador and the islands, minerals from the province of Soos, and ironstone and chert from the Iheb-el-Hadeed.

On the Geology of Caldbeck Fells, and the Lower Sedimentary Rocks of Cumberland. *By* Professor Harkness, *F.R.S.*

The district alluded to in this communication forms the northern portion of the mountainous area of the lake district of Cumberland. Caldbeck Fells, including their

eastern extremity Carrick Fell, consist of masses of plutonic and igneous rocks. On the southern slopes of these hills there is seen Skiddaw slate, which generally has a south dip; and this Skiddaw slate, as it approximates the granite of Skiddaw Forest, passes into chiastolite slate, chiastolite rock, and a pseudo-gneiss. On the south side of the granite area the same phenomena occur, but on this side hornblende rock and actinolite rock also appear. In the metamorphic rocks, and likewise in the ordinary Skiddaw slates which succeed them in position, the strike of the strata is nearly east and west, and the general arrangement of the strata seems to indicate that the plutonic and igneous masses of Caldbeck Fells form the axis of the group rather than the granite of Skiddaw Forest. With respect to the unaltered rocks of the Skiddaw district, these have been referred by Prof. Sedgwick to three groups, black Skiddaw slate, grits seen in the masses of Grassmoor, and grey Skiddaw slate containing fossils described in the Palæozoic fossils of the Woodwardian Museum. The upper grey slates are the deposits which have hitherto afforded organic remains. Last year the author obtained traces of worms from the black Skiddaw slate, the lowest member of the unaltered series, at Threlkeld, and, from a communication which the author had recently from Prof. Sedgwick, it would appear that in these low strata graptolites have been lately obtained by Mr. J. Ruthven. With regard to the lithological nature of these Skiddaw rocks, it would seem that there is a considerable change according to locality. Westward grey slates, with intercalated grits, obtain on the line of the strike of the black Skiddaw slates, leading to the inference that coarser beds supply the place of the finer black slates on the eastern margin of the area.

On the Jointing and Dolomitization of the Lower Carboniferous Limestone in the Neighbourhood of Cork. By Professor HARKNESS, *F.R.S.*

The district round Cork consists of a series of hills and valleys, the former composed of Devonian, and the latter of limestone belonging to the lower portion of the carboniferous series. In the latter are joints having three directions: one, the prevailing direction being north and south; and of the other two, one is almost horizontal and the other oblique. These joints occur in great profusion in most of the limestone localities; but in certain spots where the limestone is siliceous and bedded, the jointings are imperfect and the stratification distinct. Among these limestones there are seen in the neighbourhood of Cork dykes of dolomite, and these dykes in jointed limestone conform to the main perpendicular joints. In the limestone, where the stratification is distinct, we often find also dolomites; and these agree with the planes of stratification. The production of these dolomites appears to be subsequent to the deposition of the strata in which they occur. From the observations of Regnault it would seem that sea-water (containing sulphate of magnesia) is capable of exerting considerable influence on limestone, giving rise to carbonate of magnesia and sulphate of lime; and the phenomena exhibited by the district around Cork would lead to the inference that sea-water, finding access into rocks by joints, and in some instances along the planes of stratification, so produced the dolomitic masses.

On the Records of a Triassic Shore. By Professor HARKNESS, *F.R.S.*

The area occupied by the trias strata referred to occurs in the north-west of England and the south of Scotland. The deposits which form this series consist of argillaceous strata and sandstones, and these beds have their surfaces marked by ripples, which have resulted from the action of the wind on shallow water. Ripples of another character also occur, and these have been produced by the influence of small rills traversing a muddy shore. Tracks which have originated from the wanderings of crustaceans likewise make their appearance on the surface of the sandstones, and with these are found associated the sinuous tracks of annelids, as well as the pitted hollows which form the entrances into the burrows of these animals. Pseudomorphic crystals of salt are also exhibited in the state of small pyramidal elevations on the under sides of the sandstones, affording evidence of natural salt-pans on this Triassic shore. Small pittings mark, in many instances, the faces of the sandstones, and the surfaces reposing upon these pitted faces manifest little dome-like elevations. These have arisen from the effect of rain-drops, in most instances of a small size, resulting from fine

rain; in some instances, however, oblong impressions make their appearance, and they are the results of heavy drifting rain. All the physical conditions on these ancient shores are such as we find under favourable circumstances on the sandy and muddy coast of our present seas.

On a Model illustrative of Slaty Cleavage. By the Rev. Professor Haughton, *M.A., M.R.I.A.*

This model was intended to illustrate Mr. Haughton's views respecting the distortion of fossils by cleavage. It was made of zinc, and represented one-eighth part of the ellipsoid of compression. A moveable zinc quadrant might be placed in different positions in the model, and thus show the manner in which the line of greatest elongation of the fossils shifted with the intersection of cleavage and bedding.

Mr. Haughton stated that in all the rocks he had hitherto examined, the ellipsoid of compression was very nearly oblate, with its short axis perpendicular to the planes of cleavage.

On Fossil Stems allied to Stigmaria, *recently obtained from the Upper Beds of the Old Red Sandstone of Hook Point, Co. Wexford. By the* Rev. Professor Haughton, *M.A., M.R.I.A.*

It is well known to geologists that many plants of the genera *Stigmaria, Lepidodendron, Knorria, Sigillaria,* &c., have recently been found on this geological horizon in Donegal, Mayo, Kilkenny, Cork, and Wexford.

The specimens found at Hook Point are generally in very bad preservation. Those exhibited by Professor Haughton showed the structure of the stem well-preserved. There must have been a central bundle of vascular tissue, more or less woody; a hollow stem, and a thick bark; the latter being connected with the central vascular column by oblique spinous bundles analogous to the medullary rays of Calamites.

In the specimens exhibited by Prof. Haughton, the central vascular column was represented by a hollow tube filled with coaly matter and surrounded by the sandstone cast of the hollow stem, outside of which again appeared the carbonaceous remains of the bark of the stem, with the spinous processes on its inner surface. On the whole he considered these obscure remains of the earliest vegetation of Ireland to be allied to *Stigmaria* more closely than to any other fossil genus, and he believed that there were some peculiarities in these plants which would amply repay a careful study.

Accompanying the plant beds at Hook, was a thin bed of anthracitic coal, about 2 inches thick, the stems being found in the soft sandstone beds both above and below the coal seam. The stems were sometimes 2 feet long, and always terminated abruptly in the rock.

In conclusion, Prof. Haughton stated that geologists present at the Meeting would be able to form an excellent idea of the yellow sandstone flora by visiting the Museum of the Geological Survey, Royal Dublin Society, and Trinity College, all of which contained fine specimens of these plant remains.

On the Existence of Forces capable of changing the Sea-level during different Geological Epochs. By Professor Hennessy, *M.R.I.A.*

If, in assuming its present state from an anterior condition of entire fluidity, the matter composing the crust of the earth underwent no change of volume, the direction of gravity at the earth's surface would remain unaltered, and consequently the general figure of the liquid coating of our planet. If, on the contrary, as we have reason to believe, a diminution of volume should accompany the change of state of the materials of the earth from fluidity to solidity, the mean depth of the ocean would undergo gradual, though small alterations, over its entire extent at successive geological epochs. This result is easily deduced from the general views contained in other writings of the author, whence it appears, that if the surface stratum of the internal fluid nucleus of the earth should contract when passing to the solid state, a tendency would exist to increase the ellipticity of the liquid covering of the outer surface of the crust. A very small change of ellipticity would suffice to lay bare or submerge extensive tracts of the globe. If, for example, the mean ellipticity of the ocean increased from $\frac{1}{300}$ to $\frac{1}{299}$, the level of the sea would be raised at the equator by about 228 feet, while under

the parallel of 52° it would be depressed by 196 feet. Shallow seas and banks in the latitudes of the British Isles, and between them and the pole, would thus be converted into dry land, while low-lying plains and islands near the equator would be submerged. If similar phenomena occurred during early periods of geological history, they would manifestly influence the distribution of land and water during these periods; and with such a direction of the forces as that referred to, they would tend to increase the proportion of land in the polar and temperate regions of the earth, as compared with the equatorial regions during successive geological epochs. Such maps as those published by Sir Charles Lyell on the distribution of land and water in Europe during the tertiary period, and those of M. Elie de Beaumont, contained in Beudant's 'Geology,' would, if sufficiently extended, assist in verifying or disproving these views.

On the Conductivity of various Substances for Heat. By William Hopkins, *M.A., LL.D., F.R.S.*

The author gave an account of the results of numerous experiments which he had recently made on the conductive powers of various substances for heat. To explain the object of these experiments, he stated that if a globe of very large dimensions, like the earth, were heated in any manner and in any degree, and then left to cool by the radiation of heat from the surface, the temperature of the mass at points not too remote from its surface, and after a great lapse of time, would follow a very simple law,—the increase of temperature in descending below the surface would be proportional to the increase of depth—supposing the conductive power of the mass to be the same throughout. But if a stratum of another substance (as sedimentary matter for instance in the case of the earth) should be superimposed on the sphere, its horizontal extent being large in proportion to its thickness, the rate of increase of temperature in descending within this stratum, would be *greater* or *less* than in the other parts of the sphere, according as the conductive power should be *less* or *greater*. It would be very approximately in the inverse proportion of the conductive power. The principal object of these experiments was to ascertain whether such be the case or not.

The conductive powers of lime, clay, and sand, in the state of dry powder, are in the order in which they are now mentioned. Calcareous rocks from dry chalk to hard mountain limestone vary in their conductive powers (on the numerical scale adopted) from 1·7 to 5·5; dry sandstone rocks from 2·5 to 7·5; granite and very hard compact felspathic rocks from 5 to 10.

Hence it follows, that if the temperature observed at present in mines, Artesian wells, &c. be entirely due to heat transmitted from a central nucleus, the rate at which the temperature increases in descending below the surface of the earth, ought to be very different in different formations. It appears, however, that this rate in those mining shafts and Artesian wells which have penetrated to the greatest depths, and in which the observations are most trustworthy, in different parts of Western Europe, is nearly the same in different formations. The author compared the two cases of the Puis de Grenelle at Paris, and a vertical coal shaft at Duckenfield near Manchester. He estimated the conductive power in the former case at one-half of that in the latter, while it was found by observation that there was an increase of 1° F. for every 60 feet of depth in the former, and for about 64 feet in the latter instance; whereas these depths, instead of being in the ratio of 60 : 64, ought, according to the theory, to be in the ratio of 60 : 120. This proves that the temperatures observed in these cases cannot be due merely to heat transmitted from the interior of the earth by ordinary conduction.

The author stated also that he had investigated the influence of induration, pressure, moisture, and discontinuity, on the conductive powers of various substances, referring for details to a paper lately read before the Royal Society.

On the Geological Structure of the Dingle Promontory, Co. Kerry. By J. Beete Jukes, *M.A., F.R.S., M.R.I.A.; and* G. V. Du Noyer, *M.R.I.A.*

The authors stated that the object of this paper was twofold;—1st, to describe the very singular and interesting structure of the district, and 2ndly, to point out a very im-

portant bearing which it had on the general classification of the rocks between the top of the Silurian and the bottom of the carboniferous formations, usually classed as one thing under the terms of Old Red Sandstone, or Devonian Rocks.

Along the extreme western coast, between Sibyl Head and Slea Head, a distance of six miles, a nearly continuous section may be seen, consisting chiefly of red and greenish slates, sandstones and conglomerates, all dipping to the south at an angle of about 60°, except the red sandstones and conglomerates of Sibyl Head, which dip to the north, and repose unconformably on other red sandstones and conglomerates, the age of which is doubtful.

Between Ferriter's Castle and Doonquin the rocks are full of Upper Silurian fossils, and contain interstratified beds of contemporaneous traps and ashes, principally feldspathic. By means of these peculiar beds, an inverted S-like contortion or anticlinal and synclinal curve may be traced about Clogher Head; and if we take a certain band of red sandstone and fine conglomerate interstratified with thin ash-beds as a boundary, the fossils found below are more peculiarly Wenlock species, while those above are Ludlow, including in some places an abundance of *Pentamerus Knightii.*

The following fossils, as determined by Mr. Salter, occur in the lower or Wenlock group:—

Zoophyta.—Favosites polymorpha, alveolaris; Leperditia balthica; Halysites catenulatus; Alveolites De la Bechei; Syringopora ramulosa; Omphyma turbinatum.

Brachiopoda.—Strophomena depressa, euglypha, compressa, pecten; Athyris tumida; Rhynchonella nucula, navicula; Orthis elegantula, caligramma, rustica; Spirifer trapezoidalis, bijugosus; Atrypa reticularis.

Conchifera.—Pterinæa retroflexa, orbicularis, planulata, &c.; Avicula lineata; Grammyria cingulata, &c.

Gasteropoda.—Euomphalus funatus, alatus, lautus; Acroculia Haliotis; Murchisonia articulata?.

Crustacea.—Calymene Blumenbachii; Lichas anglicus, Barrandii; Encrinurus punctatus.

In the Upper or Ludlow group, the following species occur according to the same authority:—

Zoophyta.—Favosites multiporata, alveolaris; Heliolites interstinctus, var. Megastoma; Stenopora fibrosa; Syringopora filiformis.

Brachiopoda.—Rhynchonella Wilsoni, navicula; Orthis filosa, elegantula; Atrypa reticularis; Athyris tumida; Spirifer elevatus; Strophomena filosa; Pentamerus Knightii, galeatus.

Conchifera.—Avicula reticulata; Pterinæa rectangularis; Orthonota rigida; Goniophora cymbæformis.

Gasteropoda.—Euomphalus funatus.

Crustacea.—Phacops caudatus.

This Upper or Ludlow band strikes from Doonquin into the interior, forming the hill of Croaghmarin, and the adjacent ground. Over it may be seen a set of red shales and sandstones 800 or 1000 feet thick, which may be considered as passage beds from the Ludlow into the overlying rocks, and thus representing the Tilestones of South Wales. These pass gradually upwards into a great mass of pale green and dull purple grits and slates, which, in conjunction with Mr. Griffith, the authors call the Glengariff grits. These beds are about 6000 feet thick; they contain no fossils, but have occasional calcareous bands like the Cornstones of South Wales and Hereford, and are believed to be contemporaneous with the Cornstone group of the Old Red Sandstone of that district.

Above the Glengariff grits come a nearly equally thick series of bright red slates and sandstones, with thick beds of coarse conglomerate, containing pebbles of calcareous grit which have fossils belonging to the Llandovery sandstone, such as *Pentamerus oblongus, Petraia bina, Cyclolites lenticularis, Strophomena depressa, Encrinurus punctatus, &c.*

In addition to these are many nearly angular fragments of felspathic traps and ashes, and pieces of Silurian grits and slates. These beds, which are excellently shown along the shores of Dingle Harbour and the neighbourhood, are now called the Dingle beds. So far the continuous succession of conformable deposits is apparently unbroken, and may be tabulated as follows:—

			Feet.
Devonian.	5.	Dingle beds	5000
	4.	Glengariff grits	6000
Transition.	3.	Tilestones	1000
Silurian.	2.	Ludlow rocks	....
	1.	Wenlock rocks	....

There are now two anomalous localities to be noticed:—1st. East of Dingle Harbour, at Coosathurig, near Bull Head, some rocks consisting of red and green grits and slates, often calcareous, make their appearance, containing many common Wenlock fossils, such as *Halysites catenulatus*, *Atrypa reticularis*, &c.* Over these is a good thickness of black slates, in which nothing but fragments of encrinite stems have been found. These two sets of beds strike directly E.N.E. from Bull Head and Minard towards Cahirconree, and have on their northern side an equally straight parallel band of "Dingle beds" dipping towards them, and as seen at two localities abutting against them, either brought against them by a fault, or by some curious and distorted unconformability. The second anomalous locality is north of Ferriter's Cove, between Ferriter's Castle and Sibyl Head, where thick masses of pale salmon-coloured sandstone with some conglomerate appear to dip under the Wenlock rocks, and would therefore occupy the place of the Llandovery sandstone, to which at first they were assigned. This assumption, however, involves the supposition of such enormous faults in other parts of the district, that it has been thought better to suppose them to be a slightly modified form of the group lying over the Ludlow rocks (that which represents the Tilestones), and brought down against the lower part of the Wenlock by a fault running through Smerwick Harbour about E.N.E. and W.S.W.

Many faults are proved to exist in the district S. of Ferriter's Cove, and one or two of great magnitude running E.N.E., or nearly so from that neighbourhood, across the Mount Brandon range parallel to the axes of the anticlinal and synclical curves mentioned before. Over the whole of these highly inclined and dislocated rocks sweeps another great mass of red sandstone and conglomerate, attaining in some places a thickness of more than 3000 feet, resting quite unconformably on everything below, but dipping quite conformably under the lower beds of the carboniferous limestone, wherever that formation is to be seen, namely, on the north about Castlegregory, on the north-east and east about Tralee, and on the south-east about Castlemain. Rising from underneath the lowland of the neighbourhood of Tralee and Castle Island, this undoubted Old Red Sandstone gradually swells up into a broad anticlinal ridge, the summit of which attains an elevation of 2700 feet in Baurtregaum and Cahirconree. Between those two eminences a deep glen has been eroded in it, known as Derrymore Glen, at the bottom of which grey slates and sandstones are formed, containing Upper Silurian fossils; and to the west of Cahirconree a broad longitudinal valley, which may be called that of Anascaul, has been eroded along the anticlinal axis of the Old Red Sandstone, in which valley can be seen the rocks previously mentioned as striking from Cahirconree to the coast at Minard. On the south side of this valley the Old Red Sandstone proper, resting unconformably on the lower rocks, contains a curious local conglomerate full of angular and rounded blocks of mica-schist, a rock not known *in situ* anywhere in the neighbourhood. It is 200 feet thick in Derrymore Glen, but thins out to six feet near Minard Head. This mica-schist conglomerate is not seen in the Old Red north of the Anascaul valley, where that rock forms a bold and strong unconformable capping to many of the hills, and has several outlying patches forming the summits of peaks. One of these outlying patches also occurs on the south side, resting on Bull Head, within four miles of Dingle Harbour, being its furthest west extension on the south side of the promontory, while on the north side the Old Red Sandstone forms the capping of the ridge over Lough Anascaul, sweeps round Brandon Bay, forms Brandon Head, and runs off thence in a direct straight line for eighteen miles, dipping N.N.W. at 65°, and forming all the headlands that come within its boundary from Brandon Head to the northern Blasket Island.

In the map of the promontory of Dingle, it may be likened to the broken crust of a pasty, through the fractures and holes of which the lower rocks become visible. It

* Mr. Salter, from some fossils collected here, believes these beds to be lower than any seen at Ferriter's Cove.

appears, then, from this description, that above the Upper Silurian rocks, containing true Ludlow fossils, and having a thickness of 3000 or 4000 feet, red rocks set in quite conformable to, and graduating into these upper Silurian rocks, and that these red rocks have a total thickness of 10,000 or 12,000 feet. So far the facts are in exact accordance with those of the typical Silurian district of South Wales, &c., and the Glengariff grits and Dingle beds may be placed on a parallel with the Cornstone group of Siluria and the Cephalaspis beds of Scotland. Unfortunately this identification has not been confirmed by the discovery of any fragments of Cephalaspis or other fish remains in the Dingle district, but it is one that few persons, perhaps, will be inclined to dissent from.

Unlike Siluria, however, instead of being covered in apparent conformity by red sandstone and conglomerates forming part of an apparently continuous series, the Glengariff grits and Dingle beds are totally separated in the Dingle promontory from these overlying sandstones and conglomerates by as complete a discordance of position as can anywhere be seen, even between the Trias or New Red Sandstone, forming the base of the Secondary, and the Carboniferous, Silurian, or other Palæozoic rocks. It certainly seems to the authors impossible to group these two entirely separated and discordant things under one name like that of Old Red Sandstone, and advisable to give them two separate names.

If the upper red sandstones and conglomerates which pass conformably upwards into the base of the true carboniferous rocks should retain the name of the Old Red Sandstone, some other designation should be given to the Glengariff grits and Dingle beds. If we call them Devonian, it follows that the terms "Old Red Sandstone" and "Devonian" can no longer be considered synonymous; if, on the other hand, we keep those names as synonymous, then some other term must be introduced to designate the Glengariff grits and Dingle beds of Ireland, and the Cornstone group of Siluria and Cephalaspsis beds of Scotland. The Old Red Sandstone, which passes conformably up into the carboniferous rocks, may then be considered as the true base of that system, and with it may be classed the red sandstones and conglomerates having over them yellow sandstones often containing plants, which underlie the carboniferous slates and lower limestone shales of South Ireland, South Wales, and South England, the scraps of old red sandstones found here and there under the carboniferous limestone of North Wales and North England, and also the Upper Old Red or Yellow sandstone of Scotland, containing *Holoptychius nobilissimus*, *Cyclopteris* (*Sphenopteris*) *Hibernica*, &c.

The Middle Old Red of Scotland, or Cephalaspis beds of Miller, and also the Lower Old Red or Pterichthys beds of the same author, can, if the author's views be correct, no longer be considered as Old Red Sandstone at all. What position the true Devonian rocks of Devonshire and the Eifel beds of the Rhine will occupy with respect to the two groups of red sandstone and conglomerate (the one capping the Silurian, and the other forming the base of the carboniferous), is still uncertain. They may be either wholly or in part the contemporaries of the one or the other, or they may be intermediate between the two, deposited perhaps in the long interval which in the Dingle district was occupied by the elevation and contortion and great denudation of the lower group, and the exposure of the Silurian rocks on which they rested.

Notes on the Old Red Sandstone of South Wales.
By J. Beete Jukes, *M.A., F.R.S., M.R.I.A.*

After examining the work of the Geological Survey of the Dingle district, and seeing that the rocks, which by most geologists would be considered to be Old Red Sandstone, were there apparently conformable at their base to the top of the Upper Silurian rocks containing Ludlow fossils, and conformable at their top to the base of the carboniferous rocks, while they were themselves separated into two groups by an utter discordance and wide unconformity in their centre, the author took a very hasty run on leave of absence into South Wales, for the purpose of seeing whether anything similar could be discovered there, if the country were to be re-examined with that express object. The short time at his disposal compelled him to confine his observations to three districts:—1st, the country about Llandeilofawr, and thence to Llandovery; 2ndly, the Beacons of Brecon; 3rdly, the valley of the Usk, south of Abergavenny and east of Pontypool.

He exhibited a sketch section through each of these localities, which gave as a result the following facts:—

1st. Near Llandeilo the Upper Silurian beds are capped by a narrow band of very micaceous yellowish flags and grits, occasionally conglomeritic, and frequently fossiliferous. Below these are dull red and purple beds, alternating with grey slates and grits near Llangaddock, of which the following section is given by Sir H. De la Beche (Memoirs of Geological Survey, vol. i. p. 23):—

	Feet.
Red sandstones, hard and soft	600
Purple and red conglomerate and sandstone	65
Ditto, with micaceous bands, fossiliferous . . , ...	40
Purplish grey thin micaceous sandstone	40
Ditto, fossiliferous	330
Line of red conglomerate	...
	1075

Below are about 2000 feet of Upper Silurian rocks of the ordinary blue and grey colours.

Above this band of micaceous flags, here and elsewhere, for a distance of many miles, blood-red marls and shales set in, alternating with red sandstones, and frequently containing beds of the red or greenish or mottled calcareous sandstones, or concretionary limestones known as Cornstones. These beds are frequently and excellently shown over a band of country a mile wide and twelve miles long, from Middleton Hall to the Sawdde, near Llangaddock, and always vertical, or nearly so. Between them and the escarpment of the carboniferous limestone, to the south is a narrow richly-wooded valley in which little or nothing could be seen, except near Castell Cwm Cennen, where a mass of carboniferous limestone is brought down by a fault close against some of these vertical beds dipping at them at 20°, the Old Red Sandstone between this detached lump and the escarpment of carboniferous limestone being gently arched and contorted, and then dipping conformably under the carboniferous rocks, which it was seen to do everywhere in the neighbourhood.

Six miles east of Llangaddock, in the glen of Llechclawdd, these same rocks with strong cornstone bands dip S.E. at 70°; but on proceeding into the red district, the angle soon flattens to 45° and 20°, but without any appearance of want of conformity, while further on, five miles east by south of Llandovery, Silurian rocks and Old Red Sandstone alike lower their angles of dip to 30° or 40°; and as we proceed towards Brecknock, the Old Red Sandstone beds containing the Cornstones undulate in various directions, at angles never exceeding 5° or 10°.

What may be the exact nature of the overlap towards the west of the red rocks over the Upper Silurian, and of the upper part of the red rocks over the lower part of the same, and finally of the carboniferous rocks over the Old Red till the coal-measures rest directly on the Lower Silurian, he had no time to inquire.

2ndly. A walk across the Beacons of Brecon showed that from the Cornstones deep down in the Old Red Sandstone to the base of the carboniferous limestone, there was no apparent break. Red marls occurred throughout, containing brown and grey flagstones and sandstones with no conglomerate worthy of the name, all dipping south at about 5°.

3rdly. On examining the narrow valley of the Usk, however, near Pontypool, the Upper Silurian rocks were found to differ greatly from those near Llandeilo and Llandovery. There were no red beds in them, no appearance of any graduation between them and the Old Red Sandstone, and finally they either plunged at high angles with some contortion and obliquity towards the valley of Old Red, or as at one place dipped directly from it at 25° close to the boundary, while the Old Red Sandstone inclined towards the carboniferous escarpment, at angles varying from 10° to 30°. Here then there appeared to be a possibility, at all events, of an unconformity between the Old Red Sandstone and the Upper Silurian, and a possible concealment therefore of the lower beds of the Old Red Sandstone, which have a conformable junction with the uppermost beds of the Ludlow rocks, beneath the unconformable beds of the Upper Old Red.

This conclusion, though based on very slender evidence, is strengthened by the fact of the section here giving, with all allowances, a thickness of only 2500 feet for the

Old Red of this locality, while the section through the Beacons of Brecon shows 3000 feet for the beds above the Cornstones, and those near Llandeilo at least 5000 feet for the vertical beds of the Cornstone group, without reckoning the upper gently inclined beds near the escarpment of the carboniferous limestone. The tortuous boundary of the Upper Silurian and Old Red in the valley east of Pontypool forbids the supposition of its being a fault.

As a general result, the author stated his belief that it was possible the Old Red Sandstone (so called) of South Wales might be really two things, just as the New Red Sandstone of former days is now believed to be two things, although it is probable that from their similarity of character their separation may be more difficult in the Old than it has been in the New, and may perhaps be found to be impossible.

Mr. J. B. Jukes exhibited and described the one-inch Geological Map of Ireland, as far as published.

On the Geology of Lambay Island. By Messrs. Jukes and Du Noyer.

On the Valentia Trap-District. By G. H. Kinahan.

These traps occur in the Glengariff grit formation, and seem to have been contemporaneous with the aqueous beds. On the mainland, and on part of Begenish, they are conformable; and on the rest of Begenish, and on the Island of Valentia, they are unconformable. The lowest place in the formation where they are observed is to the south of Beenakeyraka, where they make their appearance as a dyke. It is then lost under the bog and drift, but is seen again when we go east, at the north of Glanleam, the seat of the Knight of Kerry. On Begenish, and the mainland, we meet with six different volcanic periods. The first is greenish-white compact felstone, which seems to be very local, as it is only met with at one place. Second: greenstone ash, which seems to have been very general, as it is found everywhere but on the mainland. Third: felstone, either blue, black, or greenish. It is generally separated from the last by a bed of altered slate, and has always, except on the mainland, a bed of altered slate on the top of it. This bed of felstone is found everywhere when we get a section. Fourth: the great igneous action of the period, which is a greenstone more or less felspathic. The centre of action would seem to have been at the east of Begenish, as here, where the fault is marked, there is an unconformability. It would seem also to have been near this place that the vent of the previous irruptions had taken place, as they are all represented here. The dyke in Valentia would seem to be the feeder that supplied this greenstone. It runs under the Quarry Hill, not making its appearance from Beenakeyraka until you come to the north of Glanleam, where it is lost in the sea opposite the Begenish traps. This bed is also found on the mainland, and can be traced inland for about a mile. In places it is in regular columns, and everywhere has a tendency to be columnar. Fifthly: compact felstone of a dark blue or purplish colour. It is found lying on the top of the greenstone, but dies out as we go east. To the north it is slightly hornblendic, but everywhere else it is a compact felstone. Sixthly: trappean breccia, which lies on the top of the last. It is made up of pieces of all the foregoing traps, along with slates and grits, imbedded in a green matrix. At Laght Point, and at the south-east of Begenish, there is a slight inversion.

On the Zoological Relations of the Cambrian Rocks of Bray Head and Howth. By Professor J. R. Kinahan, *M.D., M.R.I.A.*

These rocks can be no longer looked on as azoic, as in these two localities they will be found full of traces of organic life of three types at least. 1st. Zoophytic: Oldhamia, of two species, which occurs in immense beds in Bray, Co. Wicklow, and sparingly at Howth, Co. Dublin, where it was first discovered by the author in 1857. 2nd. Annelidan: tracks of wandering worms, *Arenicolites*, arranged in the same direction as the bedding found both at Howth and Bray. Worm burrows, vertical to the bedding, and arranged in pairs similar to those in the Longmynd. Worm-tubes of a new type, for which the name of *Histioderma Hibernicum* was sug-

gested. These are the membranous tubes of a tentaculated worm, which inhabited a trumpet-shaped burrow, bent up at the lower end: this occurs at Bray abundantly in a Cambrian sea-beach. 3rd. Molluscan (?): markings precisely similar to those so called in the carboniferous slates. These are from Bray. The worm-tracks of Howth do not appear to be identical with those of Bray. All the fossils at this latter place would appear to have been deposited in shallow, quiet waters.

On the Relation between the Cleavage of Minerals and the Cleavage of Rocks. By Professor KING.

On a Section across Slieve-na-Muck, Co. Tipperary. By J. O. KELLY.

On the genus Woodocrinus. *By* Prof. L. de KONINCK, *F.G.S.*; *and* EDWARD WOOD, *F.G.S.*

In the year 1854, when the genus *Woodocrinus* was first described, a single species only had been discovered.

Since then so much attention has been paid to these fossils, that we have succeeded in procuring three new species belonging to the same genus, the details of which appear to be by no means less interesting than those of the species which formed the type of the genus; and they offer some peculiarities which tend to modify and complete the characters which have been assigned to it.

We therefore think that a reproduction of the published definition of this genus, together with the modifications which the discovery of the new species has forced upon our notice, will not be a work altogether unworthy of a short memoir.

Genus WOODOCRINUS, Kon. 1854.

Generic characters.—Basal plates 5. Subradial plates 5, alternating with the basal plates. Radial plates $2\times5=10$, united laterally. Interradial plates none. Anal plates 8 to 20. Brachial pieces 4 to 10. Number of arms 10, bifurcating 1 to 5 times and furnished with pinnules. Joints of the stem cylindrical, tapering towards the outer extremity. Dome composed of a great number of small hexagonal plates, marked with star-like rays.

The calyx* of this genus takes the form of a widely-opened cup, the base of which is composed of five equal quadrangular plates, forming by their union a star with five rays. Alternating with and above these basal plates, is a row of five hexagonal plates, which in their turn alternate with the first radial pieces, to the base of which they are united by one of their sides. The radial pieces are two to each ray; these two pieces, the second of which is axillary, are cuneiform and of the same size and shape; with the exception of those which are adjacent to the anal region, all these pieces are jointed by their lateral edges, and show no trace of interradial pieces. To each ray there is a single bifurcation, consequently ten arms. The number of brachial pieces is variable; but of the species at present known, no specimen has less than four or more than ten. The arms bifurcate from one to four and sometimes five times, according to the species. The parts not laterally united are composed of alternate articulations, on the interior sides of which are inserted the pinnules, each of ten to twelve small pieces superposed one upon the other, and with a length greater than their breadth. The anal region is composed of a great number of plates (8 to 20), varying in each species. The dome appears to have been formed of small pentagonal or hexagonal regular plates. The stem, of a variable length, is composed of cylindrical articulations, alternately larger and smaller: its special character is, that, unlike the stem of all other known Crinoids, it is much thinner at the base than at the summit; this circumstance would lead us to conjecture that the *Woodocrinus* floated freely in the water, and that the stems were used to keep it upright while it floated†.

* The nomenclature is that determined by MM. de Koninck and Le Hon, in their Monograph of the Belgian Carboniferous Crinoids.

† This peculiarity seems also to point out that the genus *Woodocrinus* may form a link between the fixed Crinoids and the adult state of the genus *Comatula*. Another conjecture might be hazarded, viz. that these Crinoids were fixed on the rocks near tide-mark, and that

Relations and differences.—This genus, which has been named after the zealous amateur who alone has brought the specimens to light, is related to the genera *Cyathocrinus* (Miller), *Taxocrinus* (Phill.), and *Forbesiocrinus* (Kon.). The characters which mark their differences are easy to distinguish.

The *Cyathocrinus* has normally only four subradial plates, while the *Woodocrinus* has five, and the *Taxocrinus*, as well as the *Forbesiocrinus*, have none. Besides, the principal rays of the two last genera are composed of more than two radial plates.

The known species of this genus are *Woodocrinus macrodactylus*, *Woodocrinus expansus*, *Woodocrinus goniodactylus*, and *Woodocrinus dichodactylus*.

1. Woodocrinus macrodactylus.—As this species has been fully described in a notice on a new genus of Crinoids, read by M. de Koninck, February 1854, before the Academy of Belgium, it will not be necessary to enter into its details. We would here only add, that it is by far the most common; the thin limestone bed of a very limited area, in which this genus has alone been found, having as yet furnished but very few specimens of the other three species, while its flags are covered with the stems, arms, and calyces of the *W. macrodactylus*, twisted over each other, knotted, interlaced in almost inextricable confusion, and in such numbers as show that the ocean where they lived was not less full of life, because its denizens were so special, than those seas which have furnished to the naturalist genera much more numerous.

It may be further added, that the above beds have furnished as yet no other fossil except the *Woodocrinus* and a few teeth of *Petalodus Hastingsia* and *acuminatus* (Agass.).

2. Woodocrinus expansus.—The calyx of this species is composed of plates which bear a close resemblance to those of *Woodocrinus macrodactylus*; their position is exactly the same, and by their union they form a vase-like cup; but the diameter of these plates is greater, and they appear to be thicker and stronger than those of *W. macrodactylus*.

The basal plates are small, and the height of the exterior part is not equal to its breadth. The articulated surface of the base is very broad, and forms with the exterior surface, an angle almost equal to a right angle. The subradial plates are equal in length and breadth. The length of the first radial pieces is not equal to their breadth. Their thickness appears to be considerable. The second radial pieces are axillary and very short, though as broad as the first; from each springs two arms, one of which is generally composed of three to four and the other of four or five brachial pieces, which generally have a length three times that of their breadth. Each arm gives origin to two primary brachial rays, composed of nine and five brachial joints. The first is divided into two secondary rays, one bifurcating again once or twice before it attains its greatest length. The other, composed of about fifty brachial joints, remains single. The second divides also into two secondary rays, one bifurcating, the other single. The joints of these rays are almost semi-cylindrical, with their breadth and length nearly equal, and alternately a little thicker on each opposite side. The pinnules to which they give origin are exactly similar to those of *Woodocrinus macrodactylus*. The number of the ultimate rays of this crinoid is 80 to 100, and the total length of the arms is three times that of the calyx. The anal region, the form of which can be but imperfectly distinguished, and that only in a single specimen, appears to be composed of fewer plates than that of *Woodocrinus macrodactylus*; but these plates are broader and thicker than those of the above species, though their general disposition is the same. The dome imperfectly marked, and that in but two specimens, appears to have been large, and composed of a great number of hexagonal united to pentagonal plates, having their surface ornamented with stars in relief, not unlike the dog-toothed ornament of early English architecture. The proboscis of this species has not yet been found. The stem, in its general form, and the form of its articulations, resembles that of the *W. macrodactylus*, but it is usually larger and a little thicker.

Relations and differences.—*Woodocrinus expansus* differs from *W. macrodactylus*

their flexible stems permitted their arms to rise and fall with the tide, and that when dead they broke off, and the floating bodies were cast on the beach; which would account for the confusion with which they seem thrown together, and for the absence of any fixed base to the stems.

in the thickness of the plates which form the calyx, in the number and larger size of the anal plates, and especially in the form and greater number of the brachial rays, the first having 100 while the last has but 20 of them, whilst the joints of these rays in the first have a breadth equal to their height; in the second, where they are very short, the breadth is six times greater.

Locality.—*Woodocrinus expansus* is found associated with *W. macrodactylus*, and characterises the same beds.

3. Woodocrinus goniodactylus.—In the form of the calyx and its plates this species differs little from the two preceding ones.

The basal, the subradial, and radial plates resemble those of *Woodocrinus macrodactylus*. The axillary radial pieces are surmounted by two rays, each composed of four joints, from the last of which spring two secondary rays, one of which attains its full length without bifurcation, while the other branches off into four small rays; so that each arm contains ten rays, principal and secondary, making a total of fifty. These rays have these peculiarities, that they preserve the same breadth throughout their entire length; that their dorsal or exterior side is angular; that the last axillary joint of each ray is very large, and the joints thicken alternately at each opposite side, producing by their union a zigzag pallium, exactly like that which is found in some species of *Platycrinus* and *Actinocrinus*. The pinnules are delicate and a little more distant than in the other species. The anal region is not known. The form of the plates of the dome, of which but a small portion has been found, appears to be the same as that of the analogous plates of the preceding species. The stem is composed of cylindrical joints, so arranged that three smaller ones alternate with one larger one; this disposition gives to the stem an aspect quite different to that of the other species. Though no perfect termination has yet been found to any of the stems, there seems no reason to doubt that they have the same character as those of its other known congeners.

Relations and differences.—The angular form of the brachial rays, the peculiar mode in which the joints are articulated, as well as the different number of the rays, distinguish this species well from all the others.

Locality.—The same as that of the two preceding species.

4. Woodocrinus dichodactylus.—The form of the calyx of this species is less open and a little more elongated than that of *W. macrodactylus*, to which it has the greatest resemblance.

The basal plates are small, like those of *W. macrodactylus*, and offer no peculiarity. The subradial plates are not so broad as they are long, and are produced in a slight cup-like form. The first radial plates are as broad as they are long, and are closely united to each other. The radial axillary pieces have a length greater than their breadth, and are the principal cause of the elongation of the calyx: these axillary pieces give origin to two brachial rays composed of nine joints, rounded on their dorsal aspect, the breadth of these joints being about one-third greater than their length. The ninth joint is in its turn axillary, and from it spring two more rays, each composed of twenty-five to thirty joints, which have one of their sides alternately larger than the other. The breadth of these, like that of the joints of the primary rays, is one-third greater than their length. The total number of rays is forty. The stem is composed of joints nearly similar to each other; hence it has the appearance of being more cylindrical and less ringed than that of *W. macrodactylus*. Neither the anal region nor the dome of this species is known.

Relations and differences.—This species differs from *Woodocrinus macrodactylus* in the number of its rays, which are double that of the last, not less than by the greater tenuity of those rays. It cannot be confounded with *W. expansus*, on account of the same distinctive characters and the length of its brachial pieces. The form of the brachial joints of *W. goniodactylus* sufficiently distinguishes it from *W. dichodactylus*.

Locality.—The same as that of the three preceding, viz. a thin bed forming one of the red beds of the lead miners, and belonging to the middle carboniferous series.

Professor J. W. Mallet, of the University of Alabama, exhibited the Geological Map of that State, recently prepared by the late Prof. Tuomey to accompany his Report on the State Survey. The principal geological features of the country were noticed, and the resulting peculiarities of soil and economic advantages briefly alluded to.

Notice of the recent Advances of Palæontological Discovery in Tuscany. By Prof. Car. G. Meneghini, *of the University of Pisa.*

Tuscany is exceedingly rich in mineral products of every kind, and presents at the same time an extraordinary number of stupendous geological phenomena. Industrial interests and the love of science find there alike their inducement and recompense. It were to be desired, for the greater prosperity of the mining operations, that these were carried on with adequate capital, directed by an intelligent spirit of association. But, with respect to the scientific researches, they are ardently pursued by many *amateurs*, and are every day bringing to light new treasures.

Especially the *Palæontology* of Tuscany has been enriched of late in an extraordinary degree; and the present communication is intended to give an outline of these new discoveries.

Under the name of *Verrucano* (previously employed by Targioni), Savi, beginning with the earliest of his works, designated a vast formation which underlies the entire series of the secondary rocks, and is composed of sandstones, quartzites, talcose-schists, and arragonites, the series ending below in gneiss. This might, at that date, have been identified in a general way with the red sandstone, but palæontological data were wholly wanting to characterize it more particularly. At present we know the existence, in the middle part of this formation, of an anthracite deposit accompanied by casts of upwards of fifty species of *Sigillaria*, *Calamites*, *Annularia*, *Asterophyllites*, *Cyatheites*, *Neuropteris*, *Pecopteris*, &c., in splendid preservation; and all, or nearly all, capable of being positively identified with those of the other carboniferous beds. Besides this, in the strata of sandstone which accompany the anthracite bed, there are found in abundance *Cyathocrinus*, *Cyathophyllum*, *Orthis*, *Leptæna*, and *Spirifer*, of species equally distinguishable as belonging to the carboniferous epoch, although a mineralogical equivalent of the mountain limestone is entirely wanting. In this formation of the Verrucano, therefore, we are now enabled to distinguish the presence of the two red sandstones, the Old and the New.

The first member of our secondary rocks is composed of a bituminous, black limestone, frequently converted into beautiful black marble, or into bardiglio. We have found in it nnmerous fossils, but in a state which does not favour their identification. They seem, however, sufficient to characterize this limestone as Trassic, especially by the presence of the *Gervillia socialis*.

The series of the Lias and the Jura appear in Tuscany and in the neighbouring regions of the rest of Italy, under conditions of the greatest interest. The stratigraphic and mineralogical succession in the anticlinal curves of the metalliferous chain is composed of the following members in ascending order. First. White limestone passing into marble, more or less crystalline, of great bulk, and elevated so as to constitute the central nucleus of the anticlinal curve (Campiglia), or the most central of the peripheric bands, in case the palæozoic rocks also have been sufficiently elevated and disrupted to constitute the central area (Apuan Alps, Montagnola Senese, Elba, Cayo Argentaro). Fossil remains abound here in some spots, but are seldom recognizable; those which it has been possible to determine belong to the lower lias. Secondly. Ammonitic red limestone, so called from the abundance of ammonites which it contains, but which must not be confounded with other ammonitic red limestones in and out of Italy, since the species which it includes are almost all of the section of the *Arietes*; it has in general but little thickness. Thirdly. Another limestone of a light-grey colour, often including flint. The lower part of this affords, very sparingly, ammonites of the same species as those of the subjacent red limestone, but in the upper part we have very lately found a great number of ammonites, converted, for the greater part, into hydratic oxide of iron, and of species completely different. Fourthly. A very deep series of argillaceous schists, tawny, red, or green, all comprehended under the name of "variegated," in which, before this time, there had not been any fossils found. We have recently discovered that the lower beds of these schists, that is, those which are in immediate superposition to the grey limestone which contains the altered ammonites, are full of casts of *Posidonomya Bronnii*.

The locality of La Spezia has long been known for the abundance of ammonites discovered there by Guidoni, and illustrated by Sowerby in the work of De la Beche. Here, although the succession of the strata is much obscured by great and repeated

flexures and by an extensive fault, yet the same series exists, only the relative extent of the different mineralogical formations is different; the red and the light-grey limestones being there very little developed, while the variegated schists are much more so, and have a black limestone interstratified with them, corresponding in position to a marly limestone, which is found in other places, also interspersed among these schists, and which is remarkable for the abundance of fucoids that it contains. This Jurassic limestone with fucoids is not to be confounded with the other succeeding Cretaceous and Eocene limestones, of which we shall speak hereafter, although the species of these fucoids are in general very difficult to distinguish. Nor yet is this black limestone, intercalated among the mottled schists of La Spezia (and which is certainly of the jurassic period), to be confounded with another fossiliferous black limestone of the same locality, which belongs to the cretaceous system, and to which also we shall presently advert. It was just the confounding of these two limestones that gave rise to so many discussions and to so many false interpretations respecting the structure of the western promontory of the Gulf of Spezia. Now the ammonites described by Sowerby and many others, which occur at La Spezia in the lower beds of the variegated schists, and in the black limestone therewith interstratified, are the same as those which are to be found in a like position in the light grey limestone in the Pisan Mountains. They are of species belonging to the Lias, and many of them have been recently recognized at Hierlatz by Hauer. These same species of ammonites of La Spezia, of the Monti Pisani, and of Hierlatz, have been also recently found in a sparry limestone at Campiglia. There the variegated schists are wanting, and the limestone occupies the fissures existing in the red ammonitic limestone. Finally, another recent discovery has been made to complete the series; in the upper part of the variegated schists of La Spezia, there have been found in great abundance, casts of ammonites of species totally different from those already indicated, and perfectly recognizable as belonging to the "Oxford clay."

The black fossiliferous limestone which is in superposition to the Jurassic schists of La Spezia, is represented in the Apuan Alps, and in the Monte Pisano, by a limestone of like character, but rarely containing fossils. It is remarkable that in the same locality of La Spezia, we find it, at the distance of a few paces, decidedly metamorphosed into a most beautiful Portovenere or Portoro marble, or into white dolomite, and extremely rich in fossils exposed by the erosive action of the sea. In the Apuan Alps this forms the second peripheric band, and constitutes the lofty summits of the Pania, Pizzo d'Uccello, Pisanino, &c. The fossils which it includes prove it to be cretaceous, but with regard to its synchronism with the rocks of other localities, nothing more can be said than that it corresponds to the most ancient of the cretaceous periods, which elsewhere has been called "Neocomian." The remainder of the cretaceous rocks of the Tuscan Apennine and of the metalliferous chain, is chiefly composed of two mineralogical formations, a flaggy limestone, more or less arenaceous, denominated "Pietra forte," which constitutes the material with which the city of Florence is paved, and argillaceous schists frequently altered into *hanite* and jaspers, in contact with the ophiolitic volcanic masses. These schists, locally denominated "Galistri," also contain, more or less abundantly interspersed, a white, cream, or lead-coloured limestone, denominated "Alberese;" and finally, there appear in it beds of micaceous sandstone, "Macigno," which, at last prevailing over the schist formation, constitutes the chief bulk of our Apennines. In many places the Alberese limestone is partially replaced by some inconsiderable beds of nummulitic limestone, often containing nummulites of many species and well preserved, together with a great quantity of the other fossils which usually accompany them; sometimes, instead, with the nummulites small or fragmentary, in which case it takes the name of "*Calcare screziato*." When this member of the stratigraphic series exists, we have the means of distinguishing the portion of it, which, being lower in position than the nummulitic band, belongs to the cretaceous system, from the upper part, which, together with the nummulitic formation itself, ought rather to be considered as Eocene Tertiary. But where there does not exist any nummulitic bed, as frequently happens, it is not possible to draw any line of separation. It is to be observed, by the way, that the mineralogical character of the "Pietra forte" seems to resemble closely that of the Macigno sandstone; but not only are they in reality distinct, and their stratigraphical position *very* distinct, but moreover it was in the Pietra forte that Micheli found the

famous *Hamites* which Savi named *Hamites Michelii*; and in the same, Count Carlo Strozzi has lately discovered a very remarkable abundance of easily recognizable fossils, *Inocerami*, *Ammonites*, *Crioceratites*, *Scaphites*, &c., besides very many other fossils of strange and indeterminate forms, probably belonging to zoophytes and annelides. Some of these fossils, as for instance *Gorgonia Targionii* and *Nemertelites Strozzi*, as well as numerous fucoids, reappear, both above and below the nummulitic band, in the Macigno limestone, in its accompanying schists, and in the Alberese limestone which occurs alternately with it.

Besides the lower part of the Eocene formation, thus intimately connected with the cretacean system, an upper part may also be distinguished. This is chiefly argillaceous and calcareous; and a disturbance of the crust, anterior to its deposition, connected with the eruption of the ophiolite or diallagic serpentine, has occasioned a local unconformability of stratification between the upper and lower parts of the deposit. This upper Eocene formation is principally developed in a vast band on the northern declivity of the Apennines. On the southern side, again, it is much less so, or is chiefly calcareous, as in the valley of Tiberina, or else is entirely wanting. In this last case there is a transition also in the mineralogical character, from the Eocene Macigno to the Mollasse of the Miocene formation, which in every instance is constantly conformable to the underlying Eocene. It is then distinguishable only by the presence of the neogenic fossils.

Three other principal mineralogical formations, besides that of the Mollasse, are equally referable to the Middle Tertiary or Miocene, since they underlie the indubitable subapennine formation, the type of the Pliocene. These are, fluviatile or estuary formations, with abundant deposits of lignite, sometimes converted into anthracite (Monte Bamboli); an ophiolitic rock, perfectly similar to that of the hill of Turin; and a coarse limestone, extremely rich in fossils. The limestone formation contains numerous remains of *Anthracotherium* and other pachydermata, of chelonians, and of plants (Palms), which fix for it a high relative antiquity. The *Calcaire grossier*, on the other hand, although decidedly in infraposition to the subapennine formation, and unconformable to this (Rosignano), contains scarcely any other fossils but those of the subapennine itself.

This last, as is well known, is chiefly composed of the two mineralogical forms, blue clay, and yellow sand and gravel. Athough in general these last overlie the clay, yet their position and frequent alternations show that the two are to be looked upon as contemporaneous, with this difference only—that the sands constitute a littoral deposit, and the clays were deposited in a deeper sea. About a thousand species of Mollusca and Radiata, in a fossil state, are found in this formation, to which are to be added the Vertebrata and the plants. To this, in fact, belongs the famous bone-bed of the upper part of the Val d'Arno, consisting of a lacustrine deposit, contemporaneous with the marine subapennine, in which also are found bones and complete skeletons of the *Mastodon* and other large mammalia, besides not unfrequent remains of Reptiles, Fishes, and Cetacea. Many casts of plants have lately been discovered as well in these lacustrine deposits as in the marine littoral formation; and this flora, decidedly Pliocene (very soon to be published), will be of the utmost importance for the means it will afford of comparison with the Miocene flora, and with that actually existing.

With respect to the Pliocene fauna, the great richness of which has been mentioned, it is to be observed that every day it is found to comprise more and more of the species which hitherto were believed to belong exclusively to the Miocene formation, or which are now actually living in other seas.

To conclude, there is perhaps no place better adapted than Tuscany for the study of the Pleistocene, which is even yet in the course of formation at some points of the sea-coast, where waters charged with calcareous contents are still discharging themselves; whilst at a more or less considerable distance from the sea, it blends its characters, mineralogical, stratigraphical, and palæontological, with the littoral Pliocene formation. In the lower part of the Pliocene formation (in some places arenaceous, and in others calcareous), known under the names of *Tufo* and of *Panchina*, are found the remains of elephants, and the fossils pre-eminently subapennine; in the upper part are buried articles of human manufacture, together with shells of species still living in our seas.

In terminating these cursory notices, it may perhaps be not amiss to subjoin a few general considerations.

It would appear that the mineralogical characters of rocks are infinitely more varied and inconstant in Tuscany than anywhere else. The chief cause of the modifications locally presented by sedimentary rocks, is the abundance of the volcanic masses, themselves also extremely diversified in their nature. The eruptions of these have taken place in a chronological order, very marked and distinct, exhibited by the modifications they have induced in the various sedimentary rocks.

Except the oldest granite, the protrusion of which is probably referable to the palæozoic epoch, all the other eruptions belong decidedly to the Tertiary period.

The ophiolite or diallagic serpentine is the most ancient of them; to this succeed in chronological order, the euphotide or *granitone*; the diorite and ophite; granite with tourmaline; the masses of siderolite and amphibolite; the quartziferous porphyries; the recent serpentine without diallage; the trachytes; and finally, the basalts.

The local disturbances partially produced by these eruptions do not correspond either to the systematic divisions elsewhere established or to the palæontological differences.

The study of palæontology reveals a slow and graduated transition from the most ancient secondary strata up to those which are at present in course of formation, the fauna of each successive period assuming its own marked and constant character, while all are at the same time connected together by insensible transitions.

Finally, in Tuscany also it is evident, and perhaps in Tuscany it was first perceived, that the study of stratification is the only true key to open the secret and hitherto inaccessible paths of geological chronology.

The Quartz Rocks, Crystalline Limestones, and Micaceous Schists of the North-western Highlands of Scotland, proved to be of Lower Silurian Age, through the recent Fossil discoveries of Mr. C. Peach. *By* Sir RODERICK I. MURCHISON, *D.C.L., F.R.S.*

At the last Meeting of the British Association at Glasgow, I communicated my opinion, founded on a survey with Professor Sedgwick in 1827, and confirmed by an exploration with Professor Nicol in 1855, that the quartz rocks, limestones, and mica-schists of Sutherlandshire, in which Mr. Peach had then detected a few imperfect fossils, would prove to be of Lower Silurian age. This belief was mainly founded on the physical succession of the various rock-masses, which I described as follows in the ascending order:—

1. An ancient gneiss in part highly granitoid or traversed by granite veins.
2. Coarse grit and conglomerate of reddish colours (formerly mistaken for Old Red Sandstone).
3. Quartz rocks with intercalated limestones.
4. Micaceous schists, &c., in parts almost gneissose, with quartz rock, &c.
5. The great triple series of the Old Red Sandstone consisting of conglomerates and sandstone at the base, the Caithness ichthyolite flags in the centre, and the sandstones of Dunnet Head and the Orkneys above.

My present view (as completed by the subsequent observations of Colonel James, R.E. and of Professor Nicol in the summer of 1856, is, that the coarse red grit and conglomerate No. 2 represents the Cambrian of the British Government Surveyors; the quartz rocks, limestones, and micaceous schists, Nos. 3 and 4, having now proved to be what I suggested, viz. Lower Silurian rocks.

My earlier sections and observations having led me to conclude that the base of the Old Red Sandstone or Devonian rocks reposed transgressively and discordantly upon those quartzites and mica-schists, I naturally inferred that if the Durness limestones and quartz rock were Lower Silurian in a metamorphic state, the Upper Silurian was omitted; thus accounting for the great solution of continuity which occurs.

A recent discovery of Mr. C. Peach in the limestones of Durness has set the matter at rest: and as it has been a *quæstio vexata*,—Mr. Hugh Miller having thrown out the hypothesis that these rocks might be metamorphosed equivalents of the Old Red and

Caithness flags of the east coast, and Prof. Nicol having since suggested that they were possibly of carboniferous age, or the equivalents of the sandstones and carboniferous limestones of the South of Scotland (Quart. Journ. Geol. Soc. vol. xiii. p. 36), it is essential that my own view should be explained to the British Association, before which body the subject has already undergone discussion.

The annexed Note demonstrates, that the fossil shells last collected by Mr. Peach, and which he sent to me, are forms which characterize one of the lowest zones of the Silurian rocks of North America; and therefore the palæontological evidence is in accordance with that of the physical geologist.

I would here observe, that in tracing the Silurian rocks to the north and west, we begin to find North American types which are unknown to us in the Silurian region or in any part of England and Wales. Thus, in the South of Scotland, the *Maclurea magna* (Hall) is a well-known Ayrshire fossil, and in Ireland the *Isotelus gigas* (Dekay) is not unfrequent, and these are species which do not range further southward or eastward. It is therefore peculiarly interesting to find in a still more northern tract, a zone which is as low in the series of metamorphosed rocks in which it occurs, as the Canadian and North American calciferous sand-rock is in the regular and unaltered deposits of those countries.

As this notice is to be read at the Dublin Meeting, I venture to recall the attention of my Associates to the hypothesis which I put forth in my work, 'Siluria' (1854), viz. that the quartz rocks, micaceous schists and marbles, grey and green, of the Bins of Connemara in Galway, are also nothing more than metamorphosed 'Lower Silurians.' It is true, that no organic remains have yet been detected in any portion of these rocks, though perchance, if their weathered surfaces were searched by as keen-eyed a collector as Mr. Peach, they might afford such evidences.

My belief is founded on the fact, that the fossils found near Leenane, Maam, and other places, are none of them of higher antiquity than the Llandovery rocks (Middle Silurian), and merely indicate a passage downwards; so that the crystalline rocks which dip regularly beneath these fossil-bearing rocks may well represent the Caradoc or Bala formation, and the Llandeilo and Lingula flags, in a metamorphosed condition.

Note on the Fossils from Durness. By J. W. Salter, *F.G.S.*

It had given no little trouble, which had yet no satisfactory result, to examine and decide upon the fragments formerly collected in these altered limestones. There were always some reasons for regarding them as Lower Silurian forms, although the first reference of any of them to that period was only made with a wide margin for doubt. And so like were some fragments to those of chambered shells, and even Goniatites, that it was impossible quite to rebut Professor Nicol's notion that the whole might prove of carboniferous age, though the grounds on which he stated that belief (the presence of *Stigmaria* for instance) were far from satisfactory. Quart. Geol. Journ. vol. xiii. p. 36.

Mr. Peach's specimens, however, furnish us with a fortunate coincidence with some of the yet unpublished fossils of Canada, for a knowledge of which we are indebted to Sir W. Logan's zeal in bringing over his whole collection to England for purposes of comparison. (See Quart. Geol. Journ. vol. viii. p. 201.) In Canada, the rock which immediately overlies the Potsdam sandstone, viz. the calciferous sand-rock, contains only a few fossils, but these are characteristic of the horizon. Among them is a genus or subgenus allied to the *Raphistoma* of Hall, which has received the name *Ophileta* from Vanuxem, and consists of species which have a very wide open umbilicus angular at the edge, and with straight sides to the whorls.

In Durness the same genera and even species has been found. The Canadian specimens are far larger than the British ones, but show the same characters, and the name *Ophileta compacta* has been applied to them in MSS. and will be published in the Decade of the Canadian Survey. With them, in Canada, occurs a peculiar *Euomphalus*, or some such genus, to which the term *Maclurea matutina* is applied by Hall. And I cannot distinguish certain flattened spiral shells (with the same proportions) in the Scotch collection, from these. Again, there is a *Pleurotomaria* very like the *P. subconica*, Hall, from the Trenton limestone. The Scotch fossil resembles it in shape and in the position of the band, but has narrower whorls. Another Trenton limestone

form occurs in the presence of more than one species of *Oncoceras*, Hall. The British specimens have closer septa than those of North America, but are otherwise much like. Thus, while there is but one, or perhaps two identical species, the character of the fossils is so very similar to that of the lower limestones of America, often confounded (as we learn from Sir W. Logan) in a single calcareous band, that one is tempted to conclude that the succession in N.W. Scotland, a thick limestone reposing on a quartzite full of fucoidal markings (Nicol, *l. c.*), can be nothing else but the equivalent of the calcareous series of Canada, with its underlying Potsdam sandstone.

On the Junction of the Mica-slates and Granite, Killiney Hill, Dublin. By GEORGE V. DU NOYER, *M.R.I.A.*

The junction of the mica-slates and granite at Killiney Hill offers many points of interest to the geologist. Where the slates are in immediate contact with the granite they have become highly micaceous, and crystals of a mineral closely resembling Andalusite, as well as Andalusite itself, occur in great abundance, in some places so much so as to form a constituent of the rock. Crystals of garnet are also very common in these rocks. Throughout the entire boundary of the slates and granite, the former have a persistent dip to the east and south-east, and are singularly free from contortions, showing that where the granite acted on them its force was applied slowly, and while it was in a fluid or at least a pasty condition from heat; no violent disturbance, but a steady upheaving force, which acted uniformly on the hardened mass of the slates, and metamorphosed without crushing them: examples on a small scale, showing this, are to be seen on the shore under Obelisk Hill.

The slates which belong to the Lower Silurian group are not cleaved but foliated; large wedge-shaped masses of them, many hundred yards in length, are included in the granite; and the author explained, that when two such rocks were in junction along the flanks of mountain ranges, the detached portions of the slate might be compared to almonds on the surface of a pudding; not that they penetrated to any great depth into the granite mass, as was the idea entertained formerly by some geologists, although they may appear to be interstratified with it in bands.

Along the shores of Killiney Bay, lumps of granite are found containing galena, a small vein of which is observed in the slates close to their contact with the granite east of Killiney Railway Station. West of Toronto Terrace, the granite in some places is full of plumose mica. In the true granite north of the rock called Black Castle, a large vein of euritic granite occurs, 40 yards thick, with many smaller veins formed chiefly of quartz and felspar. Many instances were given of euritic or Elvanite veins which cut through the granite and slates, being themselves traversed by newer eurites.

The elvanite or euritic granite veins are often faulted, and the cracks thus formed filled up with infiltrated quartz.

Thin parallel veins of elvanite are often bounded at either side by a thin layer of semi-transparent sub-crystalline quartz, possibly the result of segregation from the elvanite as it shrunk in the process of cooling.

M. Du Noyer directed attention to a dyke-like tongue of granite in the hill north of Killiney Park, 3 feet 6 inches wide, which traversed the slates in a north and south direction. This dyke is cut across by elvanitic veins, which do not extend into the adjoining slates. He accounted for this singular fact by supposing that the main mass of the granite is close at hand below the surface, that the slates offered more resistance to forces disturbing both, and that the elvanite followed the lines of least resistance. The mica is very dark-coloured, and along the east wall of the dyke it is arranged in fine and well-defined laminæ oblique to the wall.

At a quarry north of the garden wall of Killiney Park, the junction of the slates and granite is well exposed. Here the dark mica assumes a remarkable appearance in the granite, being arranged in fine waved parallel lines which follow the direction of the boundary wall of the granite, and therefore dipping east at about 45°; hence the granite here has a stratified look. This singular foliation, as it may be called, of the mica crystals in the granite is best developed at the distance of a few feet from the slates, but it extends into the mass of the rock for the distance of about 20 feet, when it gradually dies out and the granite assumes its normal appearance; close to the slates the mica in the granite is disposed in small but well-defined blotches for the

distance of 18 inches, giving the rock a mottled look. In other places along the shores of and over Killiney Hill, the granite, at its contact with the slates, exhibits a thin layer of well-developed crystals of mica.

In our present state of information regarding the chemical or mechanical action which would take place in a heated granite being brought on a large scale into relation with a cold mass of slates, it is difficult to account for the appearance which the granite presents at Killiney Park Quarry ; doubtless the appearance which the mica now presents is the result of a re-arrangement of the crystals, and is, in short, a metamorphism.

General Sketch of the Districts already visited by the Geological Survey of India. By THOMAS OLDHAM, *A.M., F.R.S., G.S., &c., Superintendent of the Geological Survey of India.*

The labours of the Geological Survey of India have been conducted hitherto under great difficulties. More recently, however, the liberality of the Government of India has greatly extended the establishment of the survey, and Mr. Oldham trusted that their future progress would be rapid and effective. The only general sketch-map of the geology of India which they had was that published by the late Mr. Greenough. This was a work of great value, and gave abundant proof of the extent and labour of its author in its compilation. As might be anticipated under the circumstances, it was full of errors; and perhaps few could speak more confidently of this than himself. But at the same time it was a most valuable contribution, and would prove a most useful guide to future observers. The officer of the Geological Survey had examined several districts of considerable area in detached positions, and the results which he was able to lay before the Section might therefore appear less connected than he could wish. But every day would tend to unite them more closely; and his object was now simply to report progress, and to show that something had been done to elucidate the structure of India. Referring first to the districts to the east of the Bay of Bengal, the Tenasserim Provinces extend for about six degrees of latitude along the east shores of the Bay of Bengal. In breadth they seldom exceed more than one degree of longitude. From Siam, on the east, these provinces are separated by an interrupted range of mountains, occasionally rising to 7000 or 8000 feet high, but the general height of which is to the north about 4000, diminishing in passing southwards to 3000 feet or less. The main direction of this range is north and south; this being also the general direction of the coast line, of the minor and outlying ranges of hills, and therefore of the rivers. The geological structure is tolerably simple, although at first sight apparently complicated, from the great disturbances to which the rocks have been subjected. The central range is of granite, occasionally, but not frequently of syenitic character; itself traversed by thick veins of large crystalline felspathic granite, and often along its outer edges, or near its junction with overlying slates, characterized by the presence of tinstone as an ingredient of the mass disseminated among the other mineral constituents. This granite axis is succeeded by highly metamorphic rocks of gneissic and micaceous character, themselves cut up by numerous veins of granite, which, however, do not extend far from the junction. Upon these is a great accumulation of bluish and bluish-black earthy beds, thinly laminated, of thin-bedded grits, and of pseudo-porphyritic rock, the normal character of which is an earthy hard rock with small irregularly disseminated sub-crystalline felspar, passing, on the one hand, into slates, and, on the other, into grits, often coarse and conglomeritic. These harder rocks form all the higher grounds of the outer ranges of hills. This series, being best seen in the southern province of Mergui, has been provisionally called the "Mergui" series. The total thickness is about 9000 feet. It is succeeded unconformably by hard sandstones in thick and massive beds, with their earthy partings, generally of reddish tints, occasionally deep red and yellowish. A few beds are slightly calcareous, and in the upper portion a few thin and irregular bands of earthy blue limestone occur. Above these rest about 200 feet of soft sandstone in thin beds, upon which apparently rests the massive limestone of the country so largely seen near to Moulmein. The thickness of the entire group is about 6000 feet, and as some of its members are but seen in the northern province of Moulmein, I have provisionally called it the "Moulmein" series. To determine the age of the

older of these two groups (the Mergui) we have no data. The aspect of much of the rocks is very similar to the trappean ashes and felstones so abundant in the Silurian rocks of this country, while others are lithologically like Devonian; but these resemblances are very deceptive. The age of the Moulmein series is, however, tolerably defined by its organic contents. These appear to fix the age of the group as distinctly carboniferous. The whole of these rocks were, subsequently to their induration and disturbance, widely and greatly denuded, and on their upturned edges at intervals is found a series of conglomerates and sandstones and imperfectly coherent shales, with thick beds of coal, generally of lignitic character. None of the conglomerates are coarse; the sandstones are fine, gritty, and pebbly, or clean white quartzose grits; the shales thinly laminated; the coal itself thinly disposed in thin flaky laminæ, with earthy streakings marking its structure. In addition to the total unconformity of these rocks, the imbedded organic remains are quite distinct. They consist of dicotyledonous plants (leaves) belonging to the group of the Laureaceæ, and probably to the genus *Laurophyllum* of Göppert. In the thin papery shales which overlie the coal are also remains of fish (scales, &c.) of freshwater character; the whole referring the beds to a very recent epoch, probably corresponding in part to the pliocene of European geologists. It is curious to notice here the absence of any coal in the carboniferous rocks below, and its abundant presence in those newer beds. The total thickness of these beds does not exceed 900 to 1000 feet. They are never continuously traceable; they occur heaped up against and separated by the projecting ridges of the higher grounds, and must have been deposited when the physical conformation of the country was very similar to that now existing. They appear to be the result of a series of freshwater deposits, formed in small lake-like expansions along the lines of the great drainage valleys of the country; and to mark a line of general and greater depression between the main ridge of hills dividing Siam from the British dominions, and the outer ridges which occur between this and the sea. The direction of the main drainage of the country is determined, as already remarked, by the direction of these ranges, and is discharged into the sea through narrow rocky gorges, which have a direction nearly east and west, and which are due to lines of breakage and dislocation. To this is due the sudden alteration in the direction of the courses of the larger rivers, as may be seen on maps. Rocks similar to those situated in the Tenasserim provinces extend northwards up the course of the Salween River, and into the adjoining districts of Burmah, to the north-east of Pegu. And, again, close to the capital of Burmah, and stretching nearly north and south, as far as examined, high ridges of metamorphic rocks are again met with, consisting of gneiss, micaceous schists, and highly crystalline limestones, occasionally of a fine white colour, and largely used by the Burmese for sculpture. But the great valley of the Irrawady is, throughout a very large extent of its course, bounded on either side by a thick series of rocks, chiefly sandstones, but with massive limestones also, which are locally rich in fossils, and which, from this evidence, may be clearly referred to the eocene period. These stretch on both sides of the river as far north as Pugahu, beyond which the higher grounds recede from the river banks; but they are in all probability continued thence into Munipoor, and so united with the nummulitic rocks of the Khasi and Cachar Hills. These rocks have been considerably disturbed and broken, but have a general and prevailing strike nearly north and south, which strike, throughout many miles, has determined the general course of the River Irrawady. Their thickness is considerable, certainly exceeding 5000 feet. Above these eocene rocks, and resting upon them with slight unconformity, is a series of beds of no very great thickness, characterized by an abundance of gypsum disseminated in thin layers and veins, and in the lower beds of which occur the deposits of clays and of vegetable matter, from which are derived the larger supplies of petroleum. These rocks are well seen at Senan Kyoung ("stream of fœtid water"), and are traceable northwards to near Amarapura. In the beds which appear to form the uppermost part of this group, but which may possibly belong to another and distinct series, are found some of the fossil bones of the larger animals which occur abundantly in this district. About forty miles north of Amarapura we again meet with sandstones, shales, and coal, resting unconformably on the metamorphic rocks, and characterized by remains of dicotyledonous trees similar to, if not identical with, those found in the coal-yielding group of the Tenasserim provinces, and which are therefore referred to the same age (pliocene),

This series, so far as examined, proved of no great extent or thickness. We pass now to the Khasi Hills, which form a comparatively isolated range, rising suddenly from the great plains of Bengal in the south, and divided in the north by the valley of Assam from the great Himalaya or Bhotan range. On the southern face this range rises almost perpendicularly from the plains, which are continuous from the Bay of Bengal, with scarcely a perceptible change of level to the very foot of the hills, and, with the exception of a comparatively small thickness of metamorphic rocks at the base, are composed of nearly horizontal beds of sandstones, a few shaly layers, and limestone, long known for the abundance and beauty of the nummulites it contains. These beds dip slightly to the south, and die out towards the north, when the metamorphic rocks come to the surface in the hills. Disregarding here any details as to the older rocks, the age of the sandstones and limestones is unquestionably fixed by their organic contents, and therefore, also, the epoch of the coal, which is associated with them, as belonging to the great eocene period of geologists. No newer group of rocks is definitively seen in these hills. Along the southern face of the range there is evidence of a great dislocation extending for many miles, and possibly along the entire scarp, which has brought down to the level of the plains the rocks which are seen at the top of the hills. This line of dislocation has in all probability tended to give the nearly rectilinear direction of the escarpment; its date is fixed as at least subsequent to the formation of all the eocene rocks here seen. An older group of sandstones, considerably altered, is seen further to the north, within the hills, and also a series of highly metamorphosed schists and grits resting upon the gneissic and granite rocks; but the details of these are reserved. Passing thence still further to the north and east, at the base of the Sikkim Himalayas, under the hill station of Darjiling, another section was described. The great mass of the lofty hills is here composed of schistose rocks of various characters, considerably disturbed and contorted. These, although hitherto coloured similarly, and considered as of the same age, were decidedly different from, and more recent than, the gneissose rocks of the greatest portion of India. Near the base of the hills, and faulted against these rocks at high angles, there is a small extent of sandstone and black shales, which contain Vertebrata, Pecopteris, &c., similar to those occurring in the great coal-fields of Bengal. These fossils are peculiarly interesting, from the fact of their being changed into graphite, and occurring in beds which themselves have a very strongly marked graphitic character. They are of very limited extent; the greater portion of the sandstones, which in this section exhibit a thickness of some thousand feet, belonging to a series of much more recent date, and which has been subjected to a much smaller amount of disturbance and alteration. The exact relation of these, too, it has not been possible to observe. This upper group contains many large stems, in all observed cases prostrate, and in most cases giving evidence of great wear and long exposure previously to being imbedded; and in some of the finer and more earthy deposits an abundance of leaves occurs, of the same general character as those already noticed as occurring in Burmah and Tenasserim. This group was therefore provisionally referred to the same age (pliocene). No traces of the great nummulitic series had been observed in this district. In the more central portions of India three very large districts had been examined, to which he would now refer. One of these was to the south of Calcutta, in the district of Cuttack; the second included all the country between the great coal-field of the Damoodah, which had previously been mapped by Mr. Williams, and the River Ganges, extending northwards to Rajmahal and Bhagulpore; and the third extended along the valley of the Nerbudda from west of the Hosungabad to many miles east of Jubbulpur. For the details of the first of these he was indebted chiefly to his able assistants, Messrs. Blandford; for the last to Mr. Jos. Medlicott, who had very zealously worked it out, having to carry on the formation of a topographical map at the same time. In all these cases the sedimentary rocks, to which he would refer, formed portions of a series once more widely extended, and probably continuous over the whole country, now separated by denudation, from removal by which they have been in great part protected, by being faulted into and against the highly metamorphic gneiss, &c. which surround them. The Talcheer field extends for about 70 miles from east to west, with an average breadth of 15 to 20 miles, and is bounded both on the north and south by great parallel faults, the former of which has an aggregate throw of upwards of 2000 feet; these faults are not truly east and west, but to the

south of east and north of west. The section in ascending order of the basin shows at the base sandstone and blue shale, but slightly fossiliferous in thickness from 500 to 600 feet; over these is a series of shales and sandstones often micaceous, occasional beds of ironstone, and thin layers of coal and coally shale, giving a total thickness of about 1800 feet; and over these again is a distinct series of quartzose grits, conglomerates, and sandstones, in thickness from 1600 to 2000 feet. These three groups are unconformable each to the other; the unconformity between the two lower being, however, much less marked than that between the two upper. To the lower group, as having been first recognized and described in this district, the name of "Talcheer" series has been given; the second group, which, from its imbedded vegetable remains, was proved to be identical with the rocks of the extensive Damoodah coal-field when these were first described, has been denoted the "Damoodah" series; while the upper group, supposed to represent the great series of rocks, so magnificently seen in the Mahadeva Hills of Central India, has been called the "Mahadeva" series. Thus these series can be recognized in each of the extensive fields referred to, although with varying developments and thicknesses. At the base of the Talcheer series there is a remarkable bed, consisting of very large and only slightly rounded masses of granite and gneiss, imbedded in a fine silt, and occurring under such conditions as induce the opinion that the action of ground ice has been the cause of its formation. In the Rajmahal district, there is a very limited development of the lower beds, above which unconformably comes the Damoodah series, here exhibiting a greater extension upward than in Cuttack; but unfortunately the sequence of the rocks is interrupted by the intercalation of several successive floes of basaltic trap, the intervals between which have been marked by the continued and tranquil deposition of the mechanical rocks going on. These floes have been repeated six or seven times, and the phenomena of contact are in all cases marked; the upper layers of the mechanical deposits in contact with the trap being in all cases greatly altered, while the lower layers are in no cases changed, but rest unaltered on the degraded surface of the underlying trap. But while the actual physical sequence of the deposits cannot be here traced, the fact of their all belonging to the same great series is attested by the occurrence of some identical fossils throughout. A few species pass upwards through the series, but there is a very marked change in the general facies of the flora in the upper as compared with the lower portion of the group; the latter characterized by the abundance of Pecopteris, &c., the former by the abundance of zamia-like plants. The series, therefore, has been divided into Upper and Lower Damoodah rocks. For the details of the structure of the district, reference was made to the maps. In the Nerbudda district the series was less interrupted, and there also the same general results were obtained. The southern boundary of this great field was for a large part of its course produced by a great fault, having, *quam proxime*, the same general direction as that of the faults bounding the Talcheer field. The age, geologically considered, of these Damoodah rocks was briefly referred to. A large series of drawings of the fossil plants from them were exhibited, and the fact of the general oolitic facies of this group, especially of those from the upper beds, pointed out. The difficulty of the question was alluded to, especially in connexion with the discovery, on the one side, of several species identical with those found in these Indian rocks in the Australian coal-fields, associated with numerous animal remains distinctly referable to the lower carboniferous era; and, on the other hand, with the discovery in Cutch of other species, also identical with some of these Indian forms, in beds associated with animal remains, undoubtedly referable to the oolitic epoch. It must, however, be borne in mind that the latter forms, or those which the evidence of associated animal remains would show to be oolitic, are only found in the upper beds of the Damoodah series, while those which are common to the Australian fields are those chiefly found in the lower beds. Unfortunately, no animal remains whatever have been found with these plants in the districts examined, excepting some annelide tracts useless as distinctive forms. He preferred, under these circumstances, waiting for further evidence before giving any definite opinion as to the age of this widely-extended and important group of rocks. Mr. Oldham then stated that there seemed good reason for separating altogether from the several groups of rocks to which he had referred the whole of the great thickness of sandstones which formed the great Vindhyan range, extending almost entirely across India, from the mouths of the

Nerbudda to the Ganges at Monghyr. These appeared to be of prior date, and there was a probability that there was a great line, or a group of lines, of dislocation passing along the general line of the valley of the Nerbudda, and the effects of which might be traced over a very large area, extending towards the north-east, possibly even into the Valley of Assam. Besides the examination of these districts, which together included an area of more than 30,000 square miles, the Geological Survey had been able to add to the knowledge of the structure of the country in other ways. 1. An excellent selection of fossils from the neighbourhood of Verdachellum in Madras, for which they were indebted to Brooke Cunliffe, Esq., who had been associated with the Rev. Mr. Cay in the first examination of these fossils, had enabled them to add largely to the lists of Forbes, and to establish more conclusively than before the cretaceous age of these deposits. 2. The exertions of Captain Keatinge at Mundlaiser, to whom Mr. Oldham had pointed out the interest of the inquiry, had collected a good set of organic remains from the limestone at Bang, to the west of Mhow, which had enabled him to fix the age of those deposits as contemporary, or nearly so, with the cretaceous beds of Trichinopoly and Verdachellum. This discovery gives rise to many important speculations as to the age of other beds, and also as to the epoch of the elevation of all Central India; but more data were required before these could fairly be entered upon.

On the Ironstones in the Oolitic District of Yorkshire. By John Phillips, *M.A., LL.D., F.R.S., Reader in Geology in the University of Oxford.*

On the Discovery of Paradoxides in New England. By Professor W. B. Rogers.

On the Geological Survey of Pennsylvania. By Professor H. D. Rogers.

On the Fossils of the Dingle District. By J. W. Salter, *F.G.S.*

In this communication the author gives the detailed succession of beds in a section from Sibyl's Head on the north to Dunquin and Machin Mountain on the south, and shows from the fossil succession, as had also been demonstrated by Mr. G. Du Noyer from sections, that,—

1. There is no evidence of a great anticlinal arch, including the whole of the Silurian beds, nor of a double anticlinal divided by the mass of Clogher Head (there is however, a great flexure and fault at this point), but rather the underlying rocks, Silurian and Lower Devonian, taken in a rough sense, lie in a rude, faulted and broken synclinal, the lowest beds being respectively at Sibyl's Head on the north, and at the Bull's Head promontory east of Dingle, on the south.

2. The Wenlock and Ludlow formations are present, each well-developed, and very much like those of Britain, with some differences in the distribution of the fossils. The *Chonetes lata*, for example, a characteristic Ludlow fossil in Britain, is here most abundant in the lower Wenlock beds. Many common trilobites and shells also occur in it. Great coral beds (chiefly *Favosites polymorpha*) distinguish the Wenlock series, with abundance of a large Spirifer, *S. bijugosus*, and of Aviculæ peculiar to the district.

Pentamerus Knightii, *Rhynchonella navicula*, with several species of corals, mark the upper or Ludlow series; and there is a mass of *fucoid*-bearing strata—very remarkable and persistent—between the Ludlow and Wenlock series. At Bull's Head promontory, beds with *Pentameri* occur beneath Wenlock strata; and though these cannot be connected with the beds to the northward, there is reason to think them the equivalents of the beds at Sibyl's Head (which underlie the old red conglomerates), and that they are here brought up by enormous faults.

Lastly, attention is drawn to the fact, that this is the only Upper Silurian district of Ireland; that of Uggool, county Mayo, being rather the uppermost beds of the great Llandovery or May Hill sandstone series, so fully developed in Connemara.

On Erosion of Rivers in India.
By Hermann *and* Robert Schlagintweit.

Amongst the phænomena which characterize the course of large tropical rivers, and which, although not entirely wanting in European rivers, are still but very imperfectly developed in them, are the considerable alterations in their amount of water, recurring periodically at various seasons of the year, the amount of their suspended matter, and especially the astonishing vastness of their erosions. The erosion of the rivers consists in their constantly deepening their beds, and thus slowly, but constantly receding from the general surface.

It is indeed the erosion that is most highly and generally developed in Indian rivers, both in their lower course in the plains, and especially in their middle and upper course in the mountains, in the Himalaya and in Tibet. When correctly recognized and determined, it is moreover interesting, because it furnishes important data for the explanation of many geographical, geological and physical conditions.

But before referring to some of the numerous phænomena which stand partly in intimate connexion with the erosion of rivers, and are partly an immediate consequence thereof, we venture to illustrate the vastness and universal extension of the erosion of Indian rivers by a few examples and numbers.

The erosion is greatest in the upper course of the river, in the mountains. But even in the plains it is generally recognisable, and even here it not unfrequently attains a magnitude of 80 to 120 feet.

But in the Himalaya and Tibet the average magnitude of the erosion of the rivers, even the small ones, amounts to 1200—1500 feet, frequently exceeds 2000 feet, and in some cases, as in the upper course of the Ganges, the Sutlej and the Indus, even attains the extraordinary magnitude of 3000 feet, or, to express ourselves more generally, the bed of each of these rivers was originally in the most extreme cases, 3000 feet higher than at present; and a stratum, partly of solid rock, partly of alluvium of a thickness of 3000 feet, has been removed.

These relative magnitudes were so surprising, and the effects of erosion in general were so new a subject of investigation, that we had at first much difficulty in finding those data which might guide us in the definitive determination of the magnitude of the erosion. A summary of the various topographical forms which served us as well-defined starting-points in the determination of the magnitudes, with a short discussion of the value of each of these forms, may not be without interest.

The most essential positive data for the determination of erosion are:—

Spoon-shaped erosions in the walls of valleys; detritus, partly different from, partly identical with those still occurring in the river (which are often deposited on level surfaces); and connected lines of conglomerates of sand and freshwater shells along the steep walls of the valleys. In the Himalaya and in Tibet these often occurred, most distinctly marked, at elevations exceeding the level of the present bed of the river by 3000 feet.

In the most various rivers, and under the most multifarious conditions, some, but certainly not all the forms which we have just cited as characteristic of erosion, were always present, so that we were able in almost all places to measure the erosion directly, and to determine it more accurately than the subject would lead one to expect.

In the plains, as has already been mentioned, the magnitude of the erosion is much less, namely 80 to 120 feet, but the form is perfectly different.

From the Kaveri, Pener, Kistna and Godavery, in the south of India, and from the rivers of central India up to the plain of the Ganges, all the rivers have a distinctly marked bed of erosion, in which two stages are to be distinguished; one for the average height of the lower or ordinary height of water; and the other, the rainy river-bed, for the maximum height of the water.

The magnitude of the rainy river-bed is astonishing; in the lower course of the Ganges, the Brahmaputra and the Indus, it sometimes amounts to three or four miles, whilst the bed for the average-water level is about one mile in breadth. It is remarkable that the rainy river-bed increases in relative size the smaller the regular bed of the river is.

During nine months of the year the river runs in its regular bed, whilst its rainy bed lies dry, bearing fruitful crops on some rivers, such as the Ganges and Jumna

especially; but on others, as on the Indus and Sutlej, occupied by fine sand and shells, forming barren zones along their shores.

The overflow of the river commences within a few days after the commencement of the rainy season; as the rainy season increases, it swells so rapidly, that by careful observation, even without instruments, the increase of the river may be traced from hour to hour, like the rising of the sea during the tide of flood, until after uninterrupted rain, it completely fills both its ordinary bed and its rainy river-bed, and then has a breadth of four to five miles, a magnitude which is even far exceeded by many rivers.

The small rivers swell in the same way as the large ones, but, as we have remarked above, the rainy river-bed being larger, in proportion as the river is smaller, impassable streams are now produced, where a few days before there stood small pools filled with water scarcely an inch in depth.

So long as the river only fills its rainy river-bed, although it may be four or five miles broad, this rise has not by any means become an inundation. The mass of water is completely enclosed between the two sides of the rainy river-bed. An inundation only takes place, when the river, being swollen by unusually continuous rains, or by a greater melting of the snow in the mountains, rises above its rainy bed, which is enclosed by high banks, and then covered the neighbouring plains like a lake. Unlike the rivers of Europe, destructive inundations are rare in most Indian rivers.

The commencement of the formation of deltas is situated where the periodical rise of the river somewhat exceeds the height of the rainy bed. Inundations, but of a harmless kind, occur here regularly every year, as, for example, to the south of Dacca and Berhampoor in Lower Bengal.

But in the upper parts of almost any large river district, inundations do not occur regularly, but only occasionally, and they both take place suddenly and leave destructive effects behind them. One of the greatest inundations took place along the Indus in the summer of 1856, in its middle course between Dera Ismael Khan and Mithankot, where the river attained a breadth of nearly seven miles, its regular rainy bed extending two miles in breadth; and where, in the winter of 1856–57, after the lapse of six months, we saw profitable fishing going on in pools and channels which the Indus had left behind in its return, in places where for years only corn had grown.

That the phænomena of erosion in the plains should so many times exceed similar phænomena in Europe, may be satisfactorily explained here by the magnitude of the mass of water and its periodical accumulation at particular seasons of the year.

It is more difficult, however, to explain the enormous erosions in the mountains in the north of India. In the Himalaya itself the quantity of rain is one of the most essential causes, but here, as in Tibet, the narrowness and steepness of the valleys combine with this to increase the action extraordinarily. Hence it is that the entire eroding force of the masses of water poured down is definitely concentrated in the middle of the valleys. Waterfalls and lakes, wherever they occur, are only possible as long as the erosion has not yet reached a certain maximum. In the Himalaya and Tibet both are wanting. Lakes have been emptied by the constantly progressive erosion, as is evidenced by numerous beds of lakes now dry; in many cases the evaporation has so greatly increased, after so many watery surfaces ceased to exist, that the lakes still remaining begin to grow saline.

Waterfalls have also formerly existed, but the lateral valleys have now become so nearly equal in level, in their lower parts, with the principal valleys, in which the erosion progresses more slowly in proportion in consequence of their smaller inclination, that the subsidiary rivers unite with the principal streams with scarcely an acceleration of the current.

This gradual production of valleys, of which the bed has become some thousands of feet deeper, must naturally have had the greatest influence upon the physical conditions.

We should dread extending our remarks too far, if we did more than indicate the essential consequences of erosion, to which we may perhaps hereafter have the opportunity of adverting again; and we here mention in conclusion, only,—elevation of temperature; thermic action of the currents of air ascending the valleys along their steep walls; alternation of the conditions of moisture, and the changes, so intimately connected with these, in the distribution of plants; and extension of the glaciers.

On some Facts connected with Slaty Cleavage. *By* H. C. Sorby, *F.R.S., F.G.S.*

This communication contained an account of some of the general conclusions the author had arrived at since the publication of his papers on the subject. The microscopical mineral structure of much so-called *clay*-slates, is entirely different from the modern deposits of clay, formed from decomposed felspar, or from those occurring in strata that have undergone no subsequent chemical change. In fact they contain little or no *clay*, according to the usual acceptation of the term—no *felspar clay*,—but are often almost entirely composed of very minute plates and crystals of a peculiar mica, so that they might be called *mica clay-slates*. Though differing materially in several particulars, they are thus analogous to very fine-grained mica-schists, into which they gradually pass by the increase in the size of the crystals of mica. The form of many of the particles of which they are composed, and the manner in which they are arranged, are quite different from what are seen in rocks that have been merely deposited from suspension as mud, but are extremely like what occur when minute crystals are formed *in situ*. When not altered by subsequent mechanical movements, the structure most closely resembles that of pseudomorphs of mica or chlorite after felspar. If then it be supposed that the material had been at first deposited as a decomposed felspar clay, and that a subsequent alteration occurred, so as to convert it into a mass of minute crystals of mica, the physical structure could easily be explained; and it would not be requisite to suppose that the deposit was originally in any way different from the ordinary clays of more modern periods. That this change is physically possible is proved by the occurrence of large crystals of felspar, entirely replaced by mica and quartz; and that the chemical composition of a deposit of partially decomposed felspar is the same as that of a mixture of mica and quartz, may be readily seen by comparing their composition. This may very clearly be shown by employing the very simple formulæ for felspar, mica, and clay adopted by Gmelin in his 'Handbook of Chemistry' (Cavendish Soc. translation, vol. iii. pp. 415, 441 and 449).

$$
\begin{array}{lcl}
\text{2 equivalents of clay} & = & 48{\cdot}1 = 2Al_2O_3 + \ 4SiO_2 + 4aq \\
\text{1} \quad \text{,,} \quad \text{of felspar} & = & 51{\cdot}9 = \ Al_2O_3 + \ 6SiO_2 + KO \\
\hline
 & & 100{\cdot}0 \quad 3Al_2O_3 + 10SiO_2 + KO + 4aq \\
\text{1 equivalent of mica} & = & 70{\cdot}8 = 3Al_2O_3 + \ 6SiO_2 + KO \\
\text{4 equivalents of quartz} & = & 22{\cdot}6 = \qquad\qquad 4SiO_2 \\
\text{4 equivalents of water} & = & \ \ 6{\cdot}6 = \qquad\qquad\qquad\qquad\qquad 4aq \\
\hline
 & & 100{\cdot}0 \quad 3Al_2O_3 + 10SiO_2 + KO + 4aq
\end{array}
$$

The presence of the oxides of iron and other bases in the clay would, of course, materially modify these results; and when sufficient magnesia was present, it probably determined the formation of chloritic or steatitic slate.

The author therefore thinks that such clay-slate as is almost entirely composed of mica was originally a deposit of ordinary felspar clay, and that, probably under the action of water at a high temperature, this was altered into a mass of minute crystals of mica. The quartz appears to have either remained disseminated amongst the mica, or to have been removed and deposited in other situations; for quartz veins are of very general occurrence where this change has occurred, but are usually absent from those strata where the felspar-clay remains in its original condition. This view of the subject is of much interest in connexion with slaty cleavage, since it explains why the minute particles of mica were arranged so very promiscuously in all directions before the cleavage was developed by pressure; a fact which presented great difficulty, when it was supposed that they had been simply deposited as mud from suspension in water.

The author then proceeded to point out that there are two distinct extreme kinds of structure that have often been confounded under the term *slaty cleavage*. One of these, characteristic of the best roofing-slates of Wales, is an ultimate structural weakness, quite independent of any actual fractures or breaks of continuity, and may thus be called *ultimate-structure*-cleavage. Experiments clearly prove that this is just such a structure as would result from the rock yielding to pressure as a plastic

substance; and the amount of absolute compression when the cleavage was developed, as deduced from the form of the green spots, indicates that the amount of water squeezed out was almost exactly the same as is requisite to render clay quite plastic. The other extreme structure is a cleavage due to very close joints, often so close as to be quite undistinguishable unless a thin section is examined with the microscope, whilst the arrangement of the particles in the spaces between them is independent of the direction of the joints, and is often related to quite another plane. This kind of cleavage may therefore be called *close-joints*-cleavage; and agrees with what experiment shows would have been the result if the rock had yielded to change of dimensions like a rigid body, by the formation of close cracks. These two kinds of cleavage obey materially different laws; but at the same time, in like manner as there is a gradual passage from rigidity to plasticity, so there is also between these two kinds of structure, due to the rocks yielding in one way or the other according to the circumstances of the case; and thus the structure affords an indication of the actual condition of the rocks at the time when they were compressed; and perhaps also, in some cases, indicates whether the movements of elevation were sudden or gradual.

The paper concluded with a list of the various physical structures the author had met with in stratified rocks. A difference in the kind of chemical change that has occurred, and the previous or subsequent action of mechanical compression, when the rocks were in a condition to yield as plastic, flexible, or rigid bodies, have produced many more distinctly different structures than has been usually supposed.

On a Fossil of the Severn Drift. By the Rev. W. S. Symonds.

The excavations of the alluvial drift of the Severn at Tewkesbury Ham are nearly 40 feet deep, and the river-bed itself has been dredged to the depth of 7 feet. The *river-bed* contains osseous relics of the human race several feet below the surface of the gravel; these are associated with the remains of Roman pottery, the vertebra of a whale, and many singular round-shaped glass bottles of great thickness. The alluvial drift is a mass of clay and *brick earth*, 39 feet thick, resting upon an *ancient river-bed* of gravel and shingle, and about 37½ feet from the surface we find the fossilized antler of a large stag (Cervus). This antler is at the *base of the brick earth*, a few feet *above the gravel*. I was interested in observing the difference in the state of fossilization between the vertebra of the whale, which is little altered, and the antler of the deer, which is nearly stone. The antler is in much the same state as those mammalian remains discovered by Mr. Strickland in the drifts of Avon Valley; while we may compare the vertebra of the whale with the large crooked-horned head of a Bison, obtained by Mr. Strickland, sen., from the Avon *river-bed*. From comparison of the fossils, I am inclined to believe that the cervine antler of the Severn is the relic of an animal that lived in the period of the *Bos primigenius*, a fine skull of which is in Mr. Strickland's possession.

On a New Species of Eurypterus from the Old Red Sandstone of Herefordshire. By the Rev. W. S. Symonds.

This fossil was discovered by the parish clerk of Rowlstone, Herefordshire, and presented to the Rev. W. Wenman. Mr. Symonds examined the correlation of the rocks in which this fossil was found, and stated that they were grey sandstones of the upper Cornstones, and pass upwards into those red and chocolate-coloured sandstones which are surmounted by the "Old Red conglomerate." The Eurypterus is a Silurian fossil of the Lower Tilestones, found by Mr. Banks associated with *Pterygotus*, *Pteraspis*, and *Himantopterus* at Kington, and again in the Upper Tilestones of Kidderminster, by Mr. Roberts, with *Cephalaspis Lyelli*, *Parka decipiens*, and *Pteraspis truncatus*. "*Eurypterus pygmæus*" is found with the *Lingula cornea*, but the large form of that crustacean, now about to be described by Mr. Salter, is a different and entirely new species.

On the Geology of the Galty Mountains, &c. By A. B. Wynne, *Geological Survey.*

The author presented a north and south section across the summit of Galty More

from an outlier of the coal-measures on the south, through the carboniferous limestone, Old Red Sandstone, and Silurian, to the limestone of the Glen of Aherlow on the north. This section may be regarded as typical of the geological structure of the lofty range of the Galty Mountains, among the highest in the south of Ireland, reaching an elevation of 3014 feet above the sea. The Lower Silurian, occupying chiefly a large hollow in the centre of the range, surrounded by hills of varying height, capped with the lower conglomerate of the Old Red Sandstone, is composed of dark-coloured green, olive, red, and purple slates, grits and gritty sandstones generally striking in a nearly east and west direction, dipping at high angles, sometimes to the north, sometimes to the south, and often much contorted. Upon and unconformable to it rests the Old Red Sandstone, which, from previously existing irregularities in the surface of the Silurian, or from other causes, seems to have been very unequally deposited, as seen by referring to the section, where this formation is represented on the north by somewhat less than half its thickness to the south. It frequently presents fine examples of oblique lamination; and the only traces of organic life met with in it were some small markings of two kinds, probably annelid tracks, or fucoids, in beds of fine red sandstone, near the base of the formation, specimens of which were exhibited. The basal bed of the Old Red Sandstone is generally a thick soft conglomerate formed of red grit, pebbles, and fragments of the Silurian rocks in a purple paste, with very few pebbles of quartz. This character is not, however, constant, for it is sometimes found to be a green breccia with some rounded fragments of purple grit, and sometimes a few beds of red sandstone intervene between the conglomerate and the Silurian. Further up in the formation, at about half its thickness, occurs another marked band of conglomerate, the space between it and the basal one being occupied by red grits and sandstones. It is in one place 400 feet thick, and its pebbles are chiefly of quartz in a purple paste. Small and much rounded pebbles of syenite and trap are also found in it, as well as some fragments of green and grey grit. Above this are more red grits, becoming paler as they approach the top, and having bands of liver-coloured shale, interstratified with yellowish and coarse grey and greenish sandstone. At about 1200 feet above the last-mentioned conglomerate occur certain beds of purple ferruginous sandstone, having, when weathered, a pitted appearance. Immediately above them the author draws the very arbitrary boundary of the yellow sandstone, which, on the southern slopes of the Galties, may be about 1200 feet thick. There are just traces of some dark green gritty shales appearing in one or two places, which are probably the representatives of the carboniferous slate. The apparent thickness of all the Old Red, including the Yellow, Sandstone on the south side of the mountains may be in different places from 4000 to 4500 feet, while on the north side it is only 2000 feet thick. The carboniferous limestone is almost quite concealed by drift, and when seen is grey, compact, and sometimes slightly crystalline, containing corals and other fossils, but the Calp division does not appear. Upon it lies a thin outlier of the coal-measures, seen at the south end of the section, consisting of the lower black carbonaceous shales and thin olive grits, in which a shaft was sunk with the hope of finding culm; but the limestone was reached without success, and the search was then abandoned.

On the Tertiary Clay and Lignite of Ballymacadam, near Caher, in the County of Tipperary. By A. B. WYNNE.

This clay is found under and about the ruins of the old castle of Ballymacadam, of which little more than the foundations now remain. The mode of its occurrence is very strange, for when standing in the centre of the small hollow which it occupies, at a distance of about 100 yards, on almost every side the carboniferous limestone may be seen to protrude through the ordinary drift which is spread over the surrounding country, and which most probably once covered this isolated basin of tertiary clay, occupying an area of at the most about an acre and a half. Many pits have been sunk within this limit, of which three or four are visible, now filled with water; one small one has been recently opened to the depth of four or five feet, and in this, *in situ,* was found a lenticular mass of lignite, a specimen of which is on the table. The clay is usually white, more or less pure, and sometimes of a dun or bluish tinge, smooth to the touch, and extremely tenacious. The lignite is brown,

and occurs in different states of decomposition and alteration, but none of it remains sufficiently perfect to prove what kind of wood it was. The potter's clay is not in the lowest position in the neighbourhood, but at a slight elevation; and close to it, indeed, within the space it occupies, occur some of those natural drains so common to the mountain limestone of Ireland, expressively called by the peasantry "swallow in holes;" these carry off all the surplus water which accumulates in the pits, one in particular having been used to drain them whenever they were opened. Having sunk through about fifteen feet of white clay, containing small fragments of plants which unfit it for the manufacture of pipes, a bed of lignite is reached, of varying thickness, from which parts of trees four or five feet in length could be raised without difficulty. Beneath this occurs the purest and best clay, which is white, with sometimes a pale shade of blue, is soft, and has a soapy feel. Lower than it no person has penetrated, one of the reasons assigned being that they were prevented by springs of clear water, then bursting upwards through the clay and filling the pits, accompanied by so offensive an odour of sulphuretted hydrogen as could scarcely be endured. Even now the place is not quite free from a mitigated form of this unpleasant circumstance, which, as stated by Dr. Griffith, attends the occurrence of potter's clay and lignite in many other places in Ireland, such as at the south-eastern margin of Lough Neagh, counties of Tyrone and Antrim; in the parish of Clonoe, in county Tyrone; and near Lough Ree, in Roscommon. Of the lowest found clay, which burns white, have been manufactured very good tobacco pipes, and many articles of finer ware, as cups and saucers, &c.; while that above the lignite makes beautiful buff and dun-coloured tiles; the most inferior of it has been used for bricks. The lignite has been often used as fuel, but it gives forth a heavy and peculiar smell while burning, and is associated with black shales, traces of which were seen near the mouth of one of the pits. No shells were met with in any part of this clay.

Mr. James Yates exhibited a fossil cone, the property of Mr. T. Wetherell, F.G.S., probably from the greensand formation. He explained the appearances which prove that it belonged to the proper Coniferæ, illustrating his statement by producing specimens of recent cones belonging to the Cycadeæ.

The President exhibited another fossil from the lower Oolite, in the south of England, which, in the opinion of Mr. Yates, belonged to the Cycadeæ. This was not a cone, but a stem.

BOTANY AND ZOOLOGY, including PHYSIOLOGY.

Dr. Harvey, in taking the chair, referred to the fact, that the position he then occupied had been assigned to the late Dr. Ball. He then proposed that the meeting should adopt the following resolution:—"Resolved, that we hereby express our deep regret at the loss we have sustained by the recent sudden death of Dr. Robert Ball, an early and constant supporter of the British Association, and who had been named President of the Natural History Section on the present occasion; and that this tribute of marked respect to his memory is due not merely on account of his great merit as a naturalist and promoter of science, but much more to his personal character as a kindly, high-minded, and honourable man."

Botany.

On the finding of Cnicus tuberosus *at Avebury Hills.*
By Professor J. Buckman, *F.L.S.*

The author records the discovery of the above thistle, in the situation above named, and in the vicinity of *C. acaulis* and *C. acanthoides*. He regards it as a remarkable but not very permanent or very frequent variety of *C. acaulis*.

On the Lotus or Sacred Bean of India. By Dr. Buist. (*Communicated by* Dr. Norton Shaw.)

This plant belongs to the natural order Nelumbiaceæ, and is allied to the water lilies, and is the *Nelumbium speciosum* of botanists. Dr. Buist states that there are three species of this genus at least. The only variety he had observed in India was one with pale rose-coloured flowers, which when full-blown, but not open, formed a globe of from 6 to 7 inches in diameter. The leaf is from 14 to 16 inches long, the leaf and flowerstalks together from 6 to 8 feet in length. The leaf and flowerstalks abound in spiral vessels, which Dr. Wright says are extracted and burnt by the Hindus in the lamps placed before the shrines of their gods. Dr. Buist, however, states his conviction that the spirals of all the lotuses of India, from the Himalayas to the Line, would not make a lamp-wick a yard long the thickness of the finger. The stalks are full of air, the leaves buoyant and floating, and the flowers small, like the Tonquin bean. After describing the external appearance and uses of the plant, the author proceeded to describe—

1. *The internal structure of the root, flower, and leaf-stems.*—The stalks are filled with air, and in their construction care is taken to prevent the percolation or introduction of water.

2. *Repulsion of water from the leaves.*—This depends upon the surface of the leaves being covered with a fine fur of silvery hair, like papillæ, which, when magnified, show themselves in the form of a succession of beads, diminishing in size towards the apex. It is this structure which entangles and retains the air, and thus obtains a high degree of buoyancy. It is the same structure which enables the rose, clover, and young cabbage-leaves, young shoots of grain and grass to exhibit the pearly forms of dew-drops, and to repel water from their surface. An analogous structure performs the same function in the wings of diving birds.

3. *Respiration of the Lotus.*—The lotus leaves constantly give out air from their surface, which Dr. Buist has not examined. He found that one plant gave out from a cut stem thirty-three cubic inches of air in an hour. The greatest quantity of this air was given off two hours after sunrise.

On some Variations of British Plants. By John Hogg, *M.A., F.R.S., F.L.S., &c.*

The variations of British plants, of which the author exhibited specimens, belong to *three* species—two being distinct *varieties*, and a third might perhaps be more correctly termed a *monstrosity*.

The *first*—if *Astragalus hypoglottis*—is a very luxuriant form of it. Several specimens were gathered this last July among some ballast, on the side of a railway, in the south-east of the county of Durham. The differences in size and shape of the leaves, and in the number of the pairs of leaflets, as well as the generally more strong and upright character of the stem, made Mr. J. Hogg rather suppose that it might be a foreign species of *Astragalus*, which had been introduced with ballast. At any rate, it must be considered as a plant very distinct from the usual form of the pretty little *A. hypoglottis*.

The *second* plant presents an extraordinary transformation of the flowering spike or head of *Plantago major*.

Each single flower in the spike assumed a close pyramidal bunch of flowers, and the entire panicle also became a compact pyramid. This variety or abnormal form might be characterized as var. *pyramidalis*,—paniculis pyramidalibus densis. Smith, in his 'English Flora,' mentions a var. "*Plantago rosea*," but with which this transformed plant does not seem to agree. The rest of the plant does not differ from the usual form of *P. major*. It was discovered in a meadow, this summer, at Norton, in the county of Durham. And the *third*—the *Arbutus Unedo*—is a plant of much interest to the English botanist, for it grows naturally in the south-west of Ireland.

Mr. Hogg, having just visited the Lakes of Killarney, showed two specimens which he brought from thence, and which vary very greatly in their leaves; one having *narrow leaves*, a var. which he termed *angustifolia*; and another with *broad leaves*, having some of them rounded at their tips, he designated as var. *latifolia*.

This second variety, which appeared to grow to a larger-sized and more robust tree, he discovered on the margin of the Torc Lake, or as it is also called, the Middle Lake, whilst the narrow-leaved form he gathered on the side of the Lower Lake: both shores in those spots are of the same formation, viz. a compact limestone. Doctors Mackay and Steele make no mention of these variations of the leaves of the strawberry tree in their respective floras of Ireland.

Contributions to Vegetable Teratology. By T. MAXWELL MASTERS.

On the forms of Diatomaceæ found in Chalk. By the Rev. E. O'MEARA.

The four specimens of chalk on which my experiments were made were taken from the cliffs in the County of Antrim; and having been well washed for the purpose of removing such forms as might be attached to the surface, were dissolved in hydrochloric acid, and when thus disintegrated were boiled in dilute sulphuric acid.

In all the preparations diatomaceous forms were found, a few of which I was unable to identify with any of those figured by Mr. Smith in his 'Monograph of the British Diatomaceæ;' but all the rest, forty-two in number, were identical with those described by him as existing species.

They may be distributed into the three following classes:—

Species inhabiting fresh or brackish water	4
Marine species	7
Freshwater species	31
Total	42

It may be necessary to add, that the specimens selected were perfectly clean and free from any coating of vegetable matter, and that the one which yielded the greatest number of forms and of species had been repeatedly washed with hydrochloric acid, and the disintegrated portion removed previous to treating the remainder, which was subjected to examination.

Observations on the Plants which, by their Growth and Decomposition, form the principal part of the Irish Turf-Bogs. By D. MOORE.

It was observed that, although much has been written on this subject, and many able reports made on it, strange to say, no one had yet given any intelligible account of the species of plants which enter principally into the formation of the turf-bogs of Ireland, although so large a portion of the surface of the country is covered with them, and bog labour constitutes no inconsiderable item of productive economy in Ireland.

The varieties of bog were divided into red bog, brown bog, black or turbary bog, and mountain bog, which, although not very scientific, these being the names they are best known by, are retained. The differences of colour and consistences of matter, of which each variety is composed, were considered to depend chiefly on the localities where the substances are produced, according as they vary in different degrees of moisture, temperature, and altitude, whereby the growth and decomposition of vegetables are affected. Iron, and some other mineral substances which are generally found in peat-bogs, had no doubt something to do with the colouring, but the former combination of causes produced the effect principally.

By far the greatest portion of the bogs in Ireland consists of the kind called red bog, which varies in depth from 10 to 40 feet, or even more. This variety is the least valuable for fuel, owing to its soft fibrous consistency. It is supposed to have been formed on the sites of extensive ancient lakes, or very wet morasses, which may be inferred from the small quantity of wood found mixed up with it; besides the roots and trunks of trees being mostly found near the edges of the bog, the portions towards the centre being composed of nearly a uniform mass of the debris of the list of plants mentioned. *Narthecium ossifragum, Eleocharis cæspitosa, Carex stellulata, Schœnus nigricans, Erica tetralix,* and *Myrica gale,* might be considered the phanerogamic plants which form the framework to bear up the mass of Sphagnums and other cryptogamic species which fill up the interstices on the higher and drier spots, whilst *Menyanthes trifoliata, Comarum palustre,* and *Eriophorum angustifolium,* mix their decumbent and running stems over the surface of water, which

soon become sufficiently matted together so as to be capable of bearing up the other plants enumerated as forming this variety of bog. It was further stated, that although Sphagnums constitute a large portion of this substance, without the aid of phanerogamic plants the formation of bog could not go on at nearly so quick a ratio as it does.

In the absence of all trustworthy experiments on the growth of bog, the rate of increase could not be well ascertained, but holes out of which turf had been cut had been observed filled up with soft vegetable matter, to the depth of 1 foot in five years, which, if supposed to be ultimately compressed into one-fourth part of that bulk, after being solidified, as near an approach as can be made to the rate of increase of bog at the present day might probably be reckoned on. In limestone districts, where the larger species of *Chara* abound, whose stems and branches are always thickly encrusted with calcareous substances, the deposition of matter takes place faster than it does where those plants are not so common. The debris resulting from *Chara hispida* alone, where it grows freely, will soon fill up a shallow pool, so that plants higher in the scale of vegetation can grow on it. According to the Report of the Commissioners appointed to report on the nature and extent of the Irish bogs, upwards of a million of English acres are covered with red and brown bog, more than two-third parts of which are westward of the river Shannon.

The variety called black or turbary bog was next considered in detail, which is the most valuable for fuel, owing to the great quantity of woody matter it contains. This variety is supposed to have been formed on the sites of ancient forests, which either spread continuously over large portions of the country, or skirted the margins of morasses, as is evident from the large quantities of prostrate trunks of trees and their roots, frequently *in situ*, which are found in it. The kinds consist chiefly of *Pinus sylvestris*, *Quercus robur*, *Betula alba*, and *Alnus glutinosa*, though large quantities of yew, *Taxus baccata*, and some mountain ash, are also found in particular districts. The roots of the oaks are generally nearest the margins of the bogs, resting on the clay or marl bottoms; whilst the Scotch firs occur further towards the centre, and rest on several feet of peat, thus showing that a considerable accumulation of that substance must have taken place before they vegetated on it. These roots are frequently found one above the other, where they have grown, which has led some to suppose there have been several consecutive and distinct epochs of growth, and that some species of the trees which formed them are not now natives of Ireland. This hypothesis was not considered correct, but rather, that by the gradual growth of the bog, matter accumulated and covered the first tier of roots, and the seeds of contiguous trees, on falling and vegetating above them, grew and formed in their turn another tier, and so on up to the present surface, as a few of the trees of those ancient forests which once covered so large a portion of Ireland still exist on the Earl of Arran's property in the County Mayo at the present time.

After the plants which form this variety of bog were enumerated, the kind called mountain bog was next considered, which sometimes accumulates to a great depth on the tops of mountains, at elevations varying from 1000 to 2000 feet. The Sphagnums do not enter so largely into the composition of this kind, but their place is supplied by the grey moss, *Racomitrium lanuginosum*. The conclusions Mr. Moore has come to on this subject are the following; namely, that so far as proofs exist, the same plants which are now forming the bogs of Ireland have done so from the bottom upwards, though probably at different ratios, as drainage has increased, and that all the species are still in existence in Ireland which have ever formed any part of them. These formations he considers to be of a more recent date than the glacial epochs of geologists, with probably the exception of that at Lough Neagh, which may have been anterior to that period; but he thought it would be very hazardous to state the species which formed the fossilized wood found there.

On the Importance of a thorough understanding of the Root Principle in the Cultivation of Trees. By N. NIVEN, *Landscape Gardener and Garden Architect, &c.*

Success in connexion with the cultivation of trees, but especially *fruit-bearing* trees, is unquestionably of the utmost importance as far as matter-of-fact result goes in the production of fruit, and therefore the desirableness of a thorough understanding

of the principle in trees that chiefly conduces to the development of the same—namely, that of the root. When I thus distinctively allude to the "Root Principle," I hold that in all cases of the vegetable structure there are invariably two distinct and separate processes going forward in the development of each separate tree or plant—the one from the root upwards, which I, on a former occasion before the British Association, some years ago, in Liverpool, denominated, in contrast with the above, "the Leaf Principle,"—these being as it were the two extreme ends or turning-points in the circle of assimilation, and continually more or less in action, according to the stimuli arising from light, air, heat, and moisture,—the leaf being so far analogous to the lung in animals, and the spongiole or root to that of the heart,—the one, from the combined action of atmosphere, light and heat, conducing to the deposition of woody fibre, or the annual layer of wood in the tree, and the ramification of that wood into numerous roots and rootlets; the other, from the action of soil and its various constituents, to the development of buds, leaves, flowers, and fruit,—this beautiful and simple process of circulation passing separately up and down without intermixture, but evidently, I conceive, by distinct sets of vessels, through the alburnous layer between the bark and the wood, *externally* in Dicotyledons, and *internally* as it relates to Monocotyledons. Nor do I consider that we can ever actually change the course of these principles so as to invert their results. Cut the tree by a mortise section, as shown by the figure in Lindley's 'Theory of Horticulture,' p. 36, or rather look at the figure on p. 35, and you will see an exact representation of the embryo development of the *leaf* and *root* principles alluded to, as they became developed in the course of my experiments quoted. In short, the leaf cannot long exist without the root, nor the root without the leaf;—the one and the other are evidently equally essential to vegetable life. I stop not, however, to dwell upon the multitudinous variations and modifications of the two principles in question to be met with amongst the various genera and species of plants (as, for instance, the Cacti and other succulents), as what I above describe may be sufficient for my present purpose. To the point, then. In the management of fruit-bearing trees, whilst much doubtless will depend upon the nature and quality of soil, situation, aspect, &c., as it regards the *growing process,* much more as to *fruit bearing* will depend upon the manipulation, position, form and nature of the roots. I doubt not the growing specimens presented will readily illustrate this,—the roots being completely washed clear of the soil, so as to facilitate examination. In these two fruit-bearing dwarf trees with the numerous roots, I present specimens planted only *six months* since; in the other two specimens you have the same varieties; but on another form of roots, barren, and likely so to be for three or four years to come. It may now be said, how is all this? I will shortly endeavour to tell you. In the fruit-bearing Pear, the stock worked upon is the *Quince,* a close congener of the genus *Pyrus,* namely, *Cydonia vulgaris,* remarkable for the minute subdivision and consequent number of its rootlets, forming, as may be observed, a perfect wig. The other, but barren tree, is of the same kind and date of grafting, but worked upon the common Pear stock—or Pear grown from the seed pip—in other words, the Crab Pear, the roots of which are few, deep, and straggling. In the case of the fruit-bearing apple, the stock worked upon is what is called the *Paradise*; that is, the cutting from a certain kind of grafted apple that is highly productive of roots and rootlets, as in the case of the Quince above noticed. The other, but barren Apple, is also of the same kind and date as that just mentioned, but worked on the common or Crab stock, raised in like manner from the seed or pip, and, with the barren Pear, nearly equally deficient in fibres. The cause of this remarkable contrast of precocity on the one hand, and barrenness on the other, arises chiefly from the forms and positions of their roots. In those with fruit, the numerous spongioles or feeders of these twiggy rootlets at once answer the question as to precocity, as tending, from the immediate action of air, heat and moisture, to the rapid maturation of the ripening process and consequent development of flower-buds. On the other hand, as it regards the barren specimens presented, you at once see how different are the forms and distribution of the roots: in these they are more in the form of tap-roots running deep into the soil and subsoil, and away from the more direct influence of solar heat and air, thus lessening greatly the ripening process in the wood so conducive to flower-bud formation, and thereby otherwise going to the production of strong long-jointed water-

shoots. In many cases of deep cold soils, such trees might not bear for several years after planting.

To meet any ordinary contingency of drought, when the roots are thus kept near the surface, as in the case of the fruit-bearing specimens before you, it is necessary to counteract this by a simple application of surface *mulching*. This is one of the most essential items of treatment in the cultivation of almost all fruit trees, but especially exotic species—as the peach, nectarine, &c. Next in importance is the matter of periodical root-pruning as it is called. The most easy and effectual way in which I accomplish this is, say every second or third year, to lift the tree fairly up out of the ground and either put it back again in its old place, or, what is better, change the position somewhat. This, with a little fresh food, will do the work effectually; and the result—lots of fine plump fruit. In short, the more such wig-rooted trees are thus handled and moved about, the more will their fruit-bearing tendencies increase.

I have thus endeavoured shortly to set forth the importance of a thorough understanding of the action of the root principle in fruit-bearing trees; and I may conclude by adding that the same process applies equally to *wall* as to standard trees.

On the Remarkable Result of an Experiment upon a Fruit-bearing Tree. By N. NIVEN, *Landscape Gardener and Garden Architect, &c.*

In the book of the Revelation of St. John, it will be remembered that in the concluding chapter of that sublime portion of the sacred volume, a very wonderful tree is there described, prophetically, as bearing "twelve manner of fruits, and yielding her fruit every month." Struck with this description, the author was led to consider what possible approximation could be made towards such a result, with the means placed, under the present order of things, at his disposal. From amongst our hardy fruit-bearing trees he made choice of the Pear, fixing upon a highly vigorous and healthy young specimen then in the course of ordinary training, that had been previously worked or grafted, and which had arrived at fruit-bearing. This tree occupies a portion of the walls of his residence, having been planted on an angle of the building, occupying thereon two aspects, the one *east*, the other *south* or nearly so, the leading stem or trunk being *on* the angle, the side branches being horizontal, thus as it were at this point clasping the two walls of the house. The object aimed at, it will now be seen, was, if possible, to endeavour to construct a tree that would yield a succession of fruits *for each month of the year* complete. In the specimen fixed upon there were twenty horizontal branches on each side, thus presenting facility for the insertion by grafting of *forty varieties* or kinds of Pears. Accordingly the following selection and classification of sorts were made, put on, and labelled, viz.:—

Months.	Names.	Months.	Names.
For July	Citron des Carmes.	For December ...	Beurre Bosc.
,, ,, ...	Doyenne d'Eté.	,, ,, ...	Glout Morceau.
For August	Jargonelle.	,, ,, ...	Hacon's Incomparable.
,, ,, ...	Belle d'Aousti.	,, ,, ...	Winter Nelis.
,, ,, ...	Beurre Giffart.	,, ,, ...	Triomphe de Joidoigne.
For September. .	Beurre d'Amanlis.	For January	Beurre Langelier.
,, ,, ...	Dunmore.	,, ,, ...	Broome Park.
,, ,, ...	Franc Réal.	,, ,, ...	Winter Crassum.
,, ,, ...	Colmar d'Eté.	,, ,, ...	Knight's Monarch.
For October......	Autumn Bergamot.	,, ,, ...	Soldat d'Esperen.
,, ,, ...	Beurre Spence.	For February....	Easter Beurre.
,, ,, ...	Flemish Beauty.	,, ,, ...	Winter Beurre.
,, ,, ...	Louis Bonne of Jersey.	,, ,, ...	Joséphine de Malines.
,, ,, ...	Onondago.	For March	Crassune d'hiver.
,, ,, ...	Seckel.	,, ,, ...	Ne plus Meuris.
For November...	Bergamot d'Esperen.	For April.........	Beurre Rance.
,, ,, ...	Beurre Dièl.	,, ,, ...	Late Bergamot.
,, ,, ...	Colmar d'Aremberg.	For May..........	Beurre Rance.
,, ,, ...	Duchess d'Angoulême.	,, ,, ...	Beurre Brittoneur.
,, ,, ...	Napoleon.	For June	Suzzette de Bavey.
,, ,, ...	Thompson's.	,, ,, ...	Beurre Brettoneaw.

In the spring of 1855, the scions of these various varieties were inserted one upon each branch, all of which had been cut back to within six inches of the main stem. Thus the important process of what is called *double grafting*, or *grafting upon a graft*, was effected,—a process greatly tending to extra fruitfulness in the tree. Almost each graft of the above succeeded; and the growth of the whole came off simultaneously, and with nearly equal luxuriance, the same healthful progress resulting in 1856, but with the interesting addition of numerous sets of flower-buds on many of the grafts. In the spring of the present year the blossoms set freely, and now there are upwards of one hundred fine specimens of fruit upon so many of the sorts, that they will, in the order of their ripening, nearly, if not fully, realize the result hoped for.

Thus, in July, we had Citron des Carmes; in August, Belle d'Aousti; in September, we shall have Beurre d'Amanlis; in October, Flemish Beauty; in November, Napoleon; in December, Glout Morceau; in January, Beurre Langelier; in February, Winter Beurre; in March, Easter Beurre; in April, Late Bergamot; in May, Beurre Rance; in June, Suzzette de Bavey.

These, therefore, may fairly be looked upon as the types of the monthly classes as they will come to maturity for the table; and thus by having so many duplicates, as to their times of coming into season, under ordinary circumstances, we may reasonably expect that the circle of monthly supply from the one tree will be completed year by year. The value and importance of the above curious result, particularly where wall accommodation is limited, will at once appear; but besides this, the opportunity that will be presented for comparison between one variety and the other, and the ready ascertainment of their respective qualities and characters, must greatly tend to the enjoyment and pleasure, as well as profit, of the interested cultivator.

Remarks on the Siliceous Cells formed in the Frustules of Diatomaceæ. By J. Ralfs.

Mr. James Yates exhibited a specimen of a cone from the greensand, resembling externally certain forms of Cycads, but which from the position of the seeds, he thought must be referred to the Coniferæ. He also exhibited a specimen of the stem of a fossil Cycad, which bore a close resemblance to the recent Cycadaceæ.

Zoology.

On the Sea Fisheries of Ireland, with reference to their investigation practically and scientifically. By William Andrews.

This paper was chiefly directed to pointing out the want of knowledge that had hitherto existed in carrying out all projects connected with the fisheries of the coasts of Ireland; hence the repeated failures of Companies formed for those objects.

Habits and seasons of the fish frequenting the coasts, periods of spawning, and characteristics of spawn and spawning grounds, peculiarity of the soundings and marine animals, were branches of knowledge of essential importance, and these were treated of scientifically and practically in the paper. In the many investigations that had been held with regard to the regulations of trawling, much ignorance had been shown by fishermen (who had opposed the working of the trawl boats) in their knowledge of the nature of the spawn of the several kinds of fish which were trawled for, and this was proved in an inquiry made at Galway in 1852, where Mr. Andrews had shown that masses of a substance, which the fishermen had averred to be the spawn of fish, was nothing more than a species of sponge, the *Cliona Celata* of Johnston, and which frequently occurred in clear ground in Galway Bay in fifteen to twenty fathoms.

On a List of additions to Irish Lepidoptera. By E. Birchall.

In the list of Lepidoptera drawn up by the Rev. J. Green, there are 415 species

recorded as Irish, whilst 803 are found in Great Britain. I have paid some attention to this order of insects during the present summer, and have much pleasure in exhibiting specimens of twenty-five species captured in Ireland, and not included in Mr. Green's list. They may be thus summed up :—two Papilionidæ ; one Sphinx ; five Bombyces ; seven Noctuæ ; five Pyrales ; five Geometræ. There can be no doubt that the great discrepancy which still exists between the British and Irish lists of Lepidoptera would be much further reduced, even if a few districts of Ireland were fully worked by resident collectors : to collect successfully, local knowledge is essential, and the hurried visit of a stranger to any district generally results in disappointment. The West of Ireland, in particular, where many districts remain to the present time in much the same state as they have been for centuries, presents a wide field for research, and affords strongholds to species of great interest to the naturalist, probably to some altogether new. I may mention that ten of the species now exhibited were captured in the county of Galway. The recent discovery of *Anthrocera Minos* in the locality referred to is an earnest of what we may expect when the West of Ireland is thoroughly explored : this conspicuous insect occurs in great profusion, yet shows no disposition to wander beyond an extremely restricted locality, where it has doubtless flourished for ages. The following is a list of the new species :—

Polyommatus Ægon—not uncommon near Galway in July. *Erebia Cassiope*—several specimens captured in July at considerable elevations on the sides of the hills between Clifden and Westport. *Trochilium tipuliforme*—gardens, Dublin. *Setina Irrorella*—plentiful near Galway. *Liparis auriflua*—Howth. *Fumen nitidella*—Howth, July 1. *Clostera curtula*—Tullamore. *Endromis versicolor*—Powerscourt. *Acronycta aceris*—Malahide. *Zylophasia sublustris*—at Sugar, near Galway, in profusion. *Miana expolita*—near Galway, in plenty. The only previously recorded locality was Darlington, where the insect was discovered in 1855. *Agrotis aquilina*—Sugar, Killarney. *Teniocampa gracilis*—Sallows, Killarney. *Dasycampa rubiginea*—Ivy, Dublin. *Aplecta nebulosa*—Sugar, Galway. *Asopia flammalis*—Galway. *Botys fuscalis*—Galway. *Botys pundalis*—Galway. *Hypena crassalis*—Carrick-upon-Suir (Dr. Carte). *Nola cucullalis*—Powerscourt. *Aspilates Citraria*—Powerscourt. *Emmelesia ericetaria*—Bray. *Cabera strigillaria*—Powerscourt. *Macaria lituraria*—Powerscourt. *Eupithecia expalidaria*—Powerscourt.

Note on Peculiarities of Growth in Cæcidæ. By PHILIP P. CARPENTER.

The Cæcidæ are a group of rostriferous Gasteropoda, with shells shaped like *Dentalium*, and closed by a plug at the posterior end. There are many successive stages of growth, varying in shape and structure, but constant in the form of plug, which is of complex structure, displaying lines of growth from a central or lateral nucleus, and affords one of the best guides for the discrimination of species. As a monograph of the family was in preparation, the author sought opportunities of examining specimens from those who were interested in microscopical inquiries. They were abundant in the sponge of commerce, and lived in the worm-eaten passages of decaying shells.

On the Embryo State of Palinurus vulgaris. *By* R. Q. COUCH, *Penzance.*

At the time of the publication of Professor Bell's admirable work on British Crustacea, by some inadvertence the particulars respecting the embryo condition of *Palinurus vulgaris* were overlooked, and up to the present time have not been published. As several years have now passed, and the subject has not hitherto attracted the attention of any other observer, I beg to lay the following observations before the meeting. The metamorphoses of the decapod crustaceans may now be considered as established by observation made in every part of the world. The first announcement of the discovery came from Ireland, from experiments made near Cork by the late Mr. J. V. Thompson. The form under which the young decapods first appeared was announced as belonging to the genus *Zoea*, and all subsequently published observations have confirmed this. But in the species to which I now refer there is an important exception. Lest there should be any error on the matter, I have during the past summer again investigated the point, and have bred many thousands

in confinement, and have under the microscope seen them escaping *ex ovo*; so that there can, in my own mind, be but little doubt on the matter. The young of *Palinurus vulgaris* differs from every other species with which I am acquainted. On escaping *ex ovo* the different parts are very obscure, from being so closely folded together; but in a few minutes they are sufficiently spread out to become recognizable by a moderate magnifying power. The carapace is globularly oval, slightly pointed or produced both at the anterior and posterior margin, and is slightly contracted anteriorly so as to give the appearance of a rostrum. The abdomen is moderately long, and from four of the six annulations of which it is formed arise eight pairs of tendril-like appendages. The lateral margin of each ring is expanded into a thin projecting process, from which the articulated appendages arise. These tendrils are long, slender, and dichotomous. Their double character commences at the third joint, and afterwards they are nearly of equal length, and both are covered with strongly marked spines, termination pointed. The caudal extremity is simple, contracted, pointed, and somewhat oval. On the centre of the rostrum is a dark spot. The eyes are on enormously long and stoutly club-shaped peduncles, which are attached by very narrow and slender points. The pedunculated eyes are about two-thirds as long as the carapace. This concise description, with the figures accompanying it, will sufficiently explain the great differences between this and the young of all the other species hitherto described. So general is the Zoe form, that it has even passed into an expression with investigators of this branch of Natural History, and "the Zoe condition" has been considered equivalent to "the Embryo state" in speaking of these creatures. The contrast between the present species and that of others is very great. In them the eyes are sessile, in this enormously pedunculated; in them the feet are beneath the carapace, in this they are attached to what, for clearness, I have called the abdominal rings. Instead, therefore, of belonging to the genus *Zoe*, I would place it in *Phyllosoma* of Milne-Edwards, belonging to the Stomapodes.

On British Naked-eyed Medusæ, with notices of seven undescribed forms. *By* JOSEPH R. GREENE.

The author commenced by alluding to the progress which had been made in the study of the Naked-eyed Medusæ since the publication of Professor E. Forbes's monograph; the researches of Agassiz, Leuckhardt, and Gegenbaur being more especially dwelt on. He next gave a list of the Acalephæ which he had hitherto observed on the Dublin coast, in all amounting to twenty-five species. The Siphonophoræ were represented by the beautiful *Agalmopsis* of Sars; the Ctenophoræ by two species of *Cydippe*—one of Beroe, and the *Mnemia Norvegica*; the Steganophthalmata by all the British species, except Pelagia; and the Gymnophthalmata by thirteen species, six of which were new to science. In addition to the above, two other species of *Thaumantias* had been taken in Belfast Bay, one the *T. lineata*, the other a new species, which he proposed to name *T. Pattersonii*.

The author then proceeded to describe the seven new species which he had discovered. Three of these were referred to the genus *Thaumantias*, one to *Bougainvillea*, one to *Equorea*, one to *Steenstrupia*, and one was deemed sufficiently remarkable to induce him to establish a new genus for its reception. This last animal was particularly interesting, since it was, in all probability, identical with the medusoids produced from Coryne, as observed in Iceland by Professor Steenstrup.

The author also noticed that in this medusa reproduction took place by gemmation from the tentacles themselves, as also from the tentacular bulbs. He had observed the latter mode to occur in his new species of *Steenstrupia*. The development of medusoids from *Laomedea geniculata* was next alluded to: in all the cases which the author had himself observed, the medusoids were free and detached, nor in any instance was he able to corroborate the statement of Loven, "that the medusoids merely expanded at the summit of the 'ovigerous vesicle,' discharged ova, and then perished." He did not, however, wish to deny the correctness of Loven's description. The free medusoids were probably males. Allusion was also made to the observations of Dr. T. S. Wright and Mr. C. W. Peach. The author concluded by calling the attention of members to the study of this interesting group of animals.

Notice of a curious Monstrosity of Form in the Fusus antiquus. *By* G. C. Hyndman.

The specimen exhibited was obtained during the present summer, by dredging off Groomsport, in the county Down, by Samuel Vance, Esq., and George Murray, Esq., and kindly presented by the former to Mr. Hyndman. Unfortunately, the animal was not preserved, as the specimen was boiled along with a number of other shells, and their contents extracted before the singular form of this shell attracted notice. The author had no doubt, however, in referring to it as a curious and interesting monstrosity of the common *Fusus antiquus*, although its convolute form more nearly resembled that of the foreign genus *Delphinula*, or of *Euomphalus*. From the projection of two or three turns of the original apex of the shell, from the centre of the coil, the author considered that the abnormal form had been occasioned by some accident befalling the animal whilst in the young state, which obliged it to change the usual angle of the whorl with the central spire, and that the shell has thus become convoluted as seen.

Remarks on certain Genera of Terrestrial Isopoda. By Professor J. R. Kinahan.

These have all been included by M. Edwards under his group Cleportides, but are very improperly characterized, and the British species are comparatively unknown. A new arrangement of the genera was proposed, the characters selected as generic being the presence or absence of the so-called "epimerals" of the abdominal rings, the state of development of the frontal and lateral lobes of the head, the form and characters of the terminal abdominal ring and its appendages, and the form and structure of the filaments of the external antennæ. The following arrangement was suggested:—Family Ligidæ, genus Ligia (Brandt); family Philocidæ, genera Ligidium, Titanethes (Schiodte), Philoscia (Latreille); family Iteadæ, genera Trichoniscus (Brandt)? this genus may owe its origin to imperfect means of examination. Itea (Koch, in part);—this would appear to contain three genera in Koch, one only of which belongs to this division. Philougria (mihi), Deto (Guerin)? Porcellionidæ, Platyarthrus (Brandt)? Porcellio (Brandt); Oniscus (Latreille); Armadillidæ, Armadillo (Brandt); Armadillium (Brandt); Spherillo (Dana). The other families, Cubaridæ and Diploexochidæ, are not met with in Britain. The species met with in Britain are as follows: seven being new to that country; they are all met with in Ireland, except *P. armadilloides*, of which specimens from London are in the British Museum collection:—*Ligia oceanica*; *Philoscia muscorum*; *Philougria celer* (mihi); Philougria, generic character,—epimerals of abdominal rings rudimentary, head rounded, neither lateral nor frontal lobes, last pair of abdominal false legs uncovered, peduncle branched, external branch of the lateral appendages subulate; antennæ four; internal antennæ rudimentary; external antennæ filament subulate, smooth, five-jointed, terminal joint setaceous: *Porcellio scaber* (Brandt); *P. dilatatus* (Brandt); *P. pictus* (Brandt); *P. lævis* (Latreille); *P. pruinosus* (Brandt); *P. armadilloides* (Lereboullet); *P. cingendus* (mihi),—body elongated, smooth or slightly scabrous, frontal and lateral processes rudimentary only; last abdominal ring triangular, acute at apex: *Oniscus murarius* (Cuv.); *O. fossor* (Koch ?); *Armadillium officinale* (Brandt). All the species are from the neighbourhood of Dublin.

On a New Species of Galathea. *By* Professor J. R. Kinahan.

This species combined many of the characters of the genera *Munida* and *Galathea* as at present constituted, possessing the elongate slender claws of the former, and the flattened broad rostrum of the latter. This new species in characters is intermediate between the three known species. Professor Kinahan had named it *Galathea Andrewsii*. It is found abundantly along the east coast of Ireland, from Belfast to Dublin.

On the Cranium of Osseous Fishes and its Vertebrate and Articulate Homologies. By Professor Macdonald, *M.D.*

On the Specific Distinctions of Uria troile *and* Uria lacrymans. *By the* Rev. F. O. Morris.

The author showed that in the *Uria lacrymans* the eye is larger than in the *Uria troile,* and this, in addition to the permanent white streak from which the bird derives its name in the Latin, French and English languages, and the darker colour of old birds, he considered to establish the species distinct. He pointed out the *Corvus corone* as only distinguishable from *Corvus cornix* in a portion of the plumage; and though the birds were different in habits, so were the young and the old birds of one and the same species, *Larus marinus,* the former being gregarious and the other not. On the whole, he concluded that neither in the shape or size of the bill or feet was there any but accidental or temporary differences between individuals of the two species, as imagined by Macgillivray and others, but the distinctions he had pointed out, existing as they did "semper, ubique, et in omnibus," were permanent specific characteristics, and marked the individuality of the species.

On the Dispersion of Domestic Animals in connexion with the Primary Ethnological Divisions of the Human Race. By W. Ogilby, *F.L.S.*

The author commenced by observing that the present memoir was the complement of a paper read at the Belfast Meeting of the Association, "On the Geographical Distribution of Animals adapted to Domestication, in relation to the progressive Development of Human Civilization." The extent of the subject, and the limited time at his disposal, compelled him to confine his attention to the domestic sheep; but the same phenomena were exhibited by the Ox, Dog, Goat, &c. The leading facts of Mr. Ogilby's communication may be comprised under the following heads:—

1. That the *Ovis Brachyura,* proper to the northern parts of Europe and Asia, is the characteristic variety of the Tschudic or Ugrian races of mankind. The conquests and encroachments of the Indo-Germanic races have circumscribed the boundaries, and in some places interpolated their own proper variety (the *O. dolichura*) into the original habitat of the short-tailed sheep; but even where the aboriginal natives have been long extirpated or amalgamated with the conquering race, as in Iceland, the Faröe Islands, &c., this variety still retains its ground; whilst it is the only breed found north of the river Occa among the scattered remains of the Ugrian nations.

2. That the *Ovis dolichura* has been from time immemorial the appropriate breed of the Indo-Germanic nations, the Celts, Germans, Greeks, Romans, &c. The conquests and migrations of this widely-spread race probably introduced it into Western and Southern Europe long anterior to the historic era, as they have more recently done into North-western India, America, Australia, and partially into Northern Africa.

3. That the *Ovis platyura* was originally, as it still continues to be, the characteristic variety of the Semitic nations. It is frequently mentioned in the Bible, and has been extended by the conquests and commerce of the Arabs into Central Asia, Persia, Barbary, and along the whole East coast of Africa, as far as the Cape of Good Hope. It is this variety which furnishes the beautiful lamb-skins of Bokhara and the Crimea.

4. That the *Ovis steatopyga* was the original breed of the Mongolic nations, who still continue to cultivate it exclusively on the elevated plains of Central and North-eastern Asia and China. At a very remote period it was introduced by the conquests of these hordes into South-western Asia, and is unmistakeably mentioned by Moses in three or four texts of the Sacred Volume; but it seems never to have obtained much favour among the Semitic nations, and was not spread abroad, like the *O. platyura,* by the conquests of the Arabs.

5. That the *Ovis longicaudata* was the original, as it still continues to be the appropriate breed of the dark-skinned races of mankind both in Asia and Africa, the Æthiopians of classical writers. It is exclusively found in the Central and Western parts of Africa, from Mount Atlas to the country of the Great Damarras; and still lingers along the Southern coasts of Arabia and Persia, in both Indian Peninsulas, and the interior of some of the great islands of the Indian Archipelago.

Mr. R. Patterson read the following note of the quantity of periwinkles (*Littorina littorea*) shipped at Belfast during the years 1853, 1854, 1855, and 1856. It had been kindly furnished to him by Edmund Getty, Esq., Secretary to the Harbour Commissioners of that port:—

	Bags.	Tons.	Bushels.
1853	1034	181	3102
1854	2626	459½	7878
1855	2256	400	6858
1856	786	137	2358

Such of these as are not got in the Bay of Belfast, are principally collected on the coasts of the County Down; but the "banks" from which they have been derived are becoming exhausted, and no longer capable of supplying the demand. The quantity of periwinkles deficient is now imported from Stranraer to Belfast, and thence re-shipped for London. The local term in the north of Ireland for the periwinkle is "whelk." The "whelk" (*Buccinum undatum*) is known as the "buckie."

On a Method of applying the Compound Microscope to the sides or top of Aquaria less than two feet in height. By Professor Redfern, *M.D.*

The arrangement consists of a vertical stem, supported by a heavy foot. On the stem a short transverse tube slides vertically and rotates on the axis of the stem, as well as on an axis at right angles to the direction of the stem. This transverse tube carries a long sliding arm, made use of as a lever, with arms of very unequal length. The short arm of the lever terminates in the cup of a ball-and-socket joint. A short stem attaches a tube to the ball, and this tube allows that which carries the objective and ocular to slide through it in coarse adjustment; whilst a fine adjustment is made by acting on the long arm of the lever. The body of the microscope may thus be placed either vertically or horizontally, and placed either over an aquarium or applied to its side with equal ease in the use of the 2-inch, 1-inch, and the ½-inch objectives. For the purpose of illumination, the author employs a small mirror, which is let down into the fluid, and is capable of being moved in any direction by a simple arrangement of brass wires shown to the Section.

On Flustrella hispida. *By* Professor Redfern, *M.D.*

The author pointed out numerous inaccuracies in the existing descriptions of *Flustrella hispida*, under the names of *Flustra hispida* and *Flustra carnosa*, referring especially to the facts that no spines are ever to be found on that side of the aperture of the cell next its base; and that whilst in specimens gathered in Kincardineshire the spines are placed on the septa all round the cells, in those gathered in Dublin Bay the spines for the most part form a semicircle over the aperture, two or three only being found on the sides of the cell in rare instances. The author then described the structure of the polypide after its removal from the cell and its development by gemmation, describing its various stages from day to day, as it grew from a mere projection on the wall of the original cell, up to a complete cell with its spines and fully protruded polypide. The various characters of the perfectly formed zoophyte, with its cells set with spines, the most prominent features of its anatomical structure, and the growth of the new being from day to day, were illustrated by a series of coloured drawings made by the author with the camera lucida. Microscopical preparations were also exhibited to the Section showing the characters of the cell, and of the polypide after its removal.

Notes on some of the Animals of Tibet and India. By Hermann *and* Robert Schlagintweit.

The existence of the Yak, or Tibetan Ox (*Bos grunniens*), in a wild state has been repeatedly doubted, but we frequently found wild yaks. The chief localities where we met with them were both sides of the range which separates the Indus from the Sutlej, near the origin of the Indus, and near the environs of Gartok; but the greatest number of them was at the northern foot of the high Karakorum range, as well

as to the south of the Kuenluen, in Turkistan. In Western Tibet, particularly in Ladak, there are no more yaks in a wild state at present, though I have no doubt that they have formerly existed there. They seem to have been extirpated here, the population being, though very thin, a little more numerous than in Tibet in general. As Ladak has been occasionally more visited by travellers than any other part of Tibet, the want of the yak here has probably given rise to the idea that they are no more to be found in a wild state at all. Amongst all quadruped animals the yak is found at the greatest height: it stands best the cold of the Snowy Mountains, and is least affected by the rarefied air. But at the same time the range of temperature in which a yak can live is very limited; the real yak can scarcely exist in summer in heights of 8000 feet. We often found large herds of wild yaks, from thirty to forty, in heights of 18,600 to 18,900 English feet; and on one occasion we traced them even as high as 19,300 feet,—a remarkable elevation, as it is very considerably above the limits of vegetation, and even more than 1000 feet above the snow-line. The hybrid between the yak and the Indian cow is called Chooboo, and it is very remarkable that the chooboos are fertile. The chooboos, which are most useful domestic animals to the inhabitants of the Himalayas, are brought down to lower places, where yaks do not exist, and where consequently they cannot mix either with yaks or with the Indian cow. We had occasion to see and examine the offspring of chooboos as far as to the seventh generation, and in all these cases we found the later generations neither much altered nor deteriorated; and we were moreover informed that there was never found any limit as to the number of generations.

The Kiang, or wild horse (*Equus hemionus*), has been often confounded with the Gorkhar, or wild ass, though they differ considerably in appearance, and inhabit countries with very dissimilar climates. The kiang exists in the high cold regions and mountains of Tibet, the ass in the heated sandy plains of Sindh and Beloochistan. The kiang is found in great numbers nearly in the same localities as the yak; he does not, however, go up the mountains so high as the yak, but the range of his distribution is greater than that of the yak. The greatest elevation where we found kiangs was 18,600 English feet, whilst we traced yaks as high up as 19,300 feet. The region where the yak and the kiang are found are, in a zoological point of view, among the most remarkable and interesting of our globe. The highest absolute elevation coincides here, it is true, with the greatest height of the snow-line, or rather it causes the snow-line to be higher. But those large, high plateaus and regions, though free from snow and ice in summer, remain a desert throughout the year. The amount of vegetation on them is less than it is in the Desert between Suez and Cairo, in Egypt. Nevertheless these high, sterile regions are inhabited by numerous herds of large quadrupeds; and besides those already mentioned, numerous species of wild sheep, antelopes, and a few canine animals, chiefly wolves, as well as hares, are abundant. The herbivorous animals find here their food only by travelling daily over vast tracts of land, as there are only a few fertile spots, the greater part being completely barren. The great scarcity of vegetation, particularly the entire absence of mosses and lichens, has a very different effect, though an indirect one, on the occurrence of birds. Those small plants are the chief abode of insects: the want of mosses and lichens, coinciding with a total absence of humus, limits, therefore, to its minimum the occurrence of insects, the exclusive food of small birds in all extremely elevated parts of the globe, where grains are no more found. We indeed met, travelling twenty consecutive days between heights of 14,000 to 18,200 feet, only with three individuals belonging to a species of *Fringilla*, but occasionally a few large carnivorous birds, as vultures, were met with.

The Gorkhar, or wild ass (*Asinus onager*), an animal which, as I mentioned before, has been often confounded with the Kiang, or wild horse, inhabits chiefly the rather hilly districts of Beloochistan, part of the sandy plains of Sindh; and a similar animal is to be found, if I am not mistaken, to the westward of Beloochistan, in Persia, which is called Koolan (*Equus hemippus*). Dr. Barth lately told me, that, according to the description I gave him, he thinks the asses he saw in Africa identical with the Gorkhars, or wild asses, of Sindh and Beloochistan.

I will now try to give an explanation about the fabulous Unicorn, or animal which is said to have one horn only. This animal has been described by Messrs. Huc and Gabet, the famous travellers in Eastern Tibet, according to information they received,

as a species of antelope with one horn placed unsymmetrically on his head. When my brother Hermann was in Nepaul, he procured specimens of horns of a wild sheep (not of an antelope) of very curious appearance. At first sight it seemed to be but one horn placed on the centre of the head; but on closer examination, and after having made a horizontal section of the horn, it was found to consist of two distinct parts, which were included in a horny envelope, not unlike to two fingers put in one finger of a glove. The animal when young has two separate horns, which are however placed so close to each other, that the interior borders begin very soon to touch each other; later, by a slight consequent irritation, the horny matter forms one uninterrupted mass, and the two horns are surrounded by this horny substance, so that they appear at first sight to be but one.

In conclusion, allow me to say a few words about migratory birds. There are no migratory birds in the Himalayas; we nowhere and at no season found flocks crossing the Himalayas, as many birds of Europe cross the Alps, between Italy and Germany. The Himalayan birds do not change their abodes on a large scale; the different various heights themselves afford them the opportunity to select the climate they require in different seasons. In the plains of India, however, chiefly in Bengal, a large number of birds disappear during the breeding time; they do not, however, leave India altogether, but select their abodes in the lower, impenetrable jungles of the delta of the Ganges and Brahmapootra, called the Sunderbunds, where they were found by my brother Hermann in large quantities, whilst at the same time they had entirely disappeared in Bengal Proper.

On the Reproductive Zooids of Comatula rosacea. *By* Professor Wyville Thompson.

On Dredging in Weymouth Bay. By W. Thompson.

The results of a day's dredging in Weymouth Bay, by Mr. Thompson, were read, by which it appeared that he had obtained thirteen species of Conchiferous Mollusks; two of fish; eight of Crustacea; two Nudibranchiate Mollusks; four Tunicated Mollusks; four Actiniadæ; one Cirrhipede; one Medusa (floating); three Sponges; three Radiata; and nine Annelides.

Mr. Thompson also drew attention to the gregarious habit of *Doris bilamellata* in early spring, when they approach the shore for the purpose of depositing their coils of ova.

He also drew attention to the constancy with which certain parasites in the different families of nature are always found in the same species, and he instanced *Adamsia palliatia* as always found on *Pagurus Prideauxii*; *Sagartia parasitica* on *Pagurus Bernhardus*; *Halichondria suberea* on *Pagurus Forbesii*, and very seldom on *Pagurus lævis*; *Hydractinia echinata* on *Pagurus Bernhardus*. *Pecten opercularis*, when young, is always attached by a byssus, and *Pecten varius* is attached throughout its existence.

The dredging ground was on a rough shingle and coralline bottom in 10 fathoms water, in Weymouth Bay, about four miles from the shore.

Notes of a Visit to Mitchelstown Caves. By Dr. E. Percival Wright, *Director of the Dublin University Museum.*

The author stated, that in company with Mr. Halliday, he, in the early part of August 1857, explored the extensive limestone caverns situated in the valley of Mitchelstown, between the Galtee and the Knockmildown ranges of mountains; the object of the visit being to examine whether any of the curious blind animals, so well known as inhabiting the Carniola and other caves, could be found in Ireland.

He gave a brief sketch of the geology of the district, of the various blind insects found on the continent and described by Schiodte, and of the Mitchelstown Cave, of which a ground-plan was exhibited; and then stated that in the interior of the cave, and near some small pools of water formed by the dropping from the roof, specimens of a small white Lipura were discovered. This insect comes very near to the species figured by Schiodte, found in Adellesburg Cave; but on a very careful examination

by Mr. Halliday, many differences were detected, more particularly the total absence of ocelli, fourteen of which are figured by Schiodte on each side of the head of his Lipura; but not a trace of ocelli was found in the Mitchelstown Cave specimens. Mr. Halliday observed that there were some other points, in which Schiodte's observations, or at least his interpretation of them, were at variance with what is known of the common structure of this family. Hence he was led to hesitate as to the importance to be attached to the differences noted. His Lipura, as well as another species of the family (certainly blind), *Tritomurus scutellatus*, had both been ascertained to have an extensive range in the caves of the Austrian territory, and it did not seem so improbable that they should occur in similar situations even in these islands. The other species found in the Mitchelstown caves having distinct eyes, and the structure of the anal fork agreeing with *Macrotoma*, could not be confounded with the last-named insect.

The list of the proper subterranean Fauna of the European caves (independent of the immigrant animals which occur on the outer world also) had been largely added to since Mr. A. Murray's paper "On Blind Insects and Blind Vision" was written. Mr. Halliday submitted a list which, in its turn, would doubtless soon be antiquated by the fresh investigations so diligently pursued by the Austrian naturalists. The present list comprises:—Vertebrata, 1; Insecta, 31; Arachnida, 7; Myriapoda, 1; Crustacea, 5; Annelida, 1; Mollusca, 17.

Physiology.

The President of the Physiological Sub-Section said that it would be in the recollection of several persons present, that in the year 1835, when the British Association met first in Dublin, a Physiological or Medical Section had been formed and had worked with great success, and that many important additions to science had emanated from its labours. Since that period, however, at the meetings of the Association which took place in the principal towns throughout the empire, no Physiological Section existed, nor indeed had it been originally intended in the arrangements for the present meeting in Dublin to establish any such Section as a distinct one. It had been found, however, that many distinguished scientific medical men had assembled in the city, representing not merely England and Scotland, but several of the Continental countries, and even America, and it was determined, even at the present late hour, to organize a Sub-section, in which the labours of these eminent medical men could be made available for the promotion of science, and he (Professor Harrison) was happy to congratulate the meeting on the distinguished array of gentlemen now assembled in this room.

On certain a priori *Principles of Biology. By* Professor Alison, *M.D.*

The writer stated that there were certain principles which should be admitted as ultimate facts, as stated, very accurately, by Cuvier, because *exceptions* to the laws of inorganic matter; and that they formed the same basis for physiological science as the principles of Gravity, the Inertia of Matter, or the Laws of Chemistry, for the sciences of dead matter, and as certain inductive principles to the science of morals. It might be said that the object of the paper was to apply the logic of the Scotch school of metaphysics to physiological science; but on account of the recent illness of the distinguished author, the communication was incomplete*.

* Dr. Gairdner, of Edinburgh, as a pupil of Professor Alison, explained the nature and object of his distinguished preceptor's views, which he said were chiefly directed to oppose the modern tendency of medical investigation, which he regarded as likely to degrade the science to that of a subordinate department of chemistry on the one hand, and of mechanical science on the other, omitting the one consideration of that indispensable though less intelligible class of phenomena which were known to *be vital*.

A Brief Suggestion, recommending a more complete Compilation of the Facts illustrating the Physiology of Vegetable and Animal Secretions. By R. Dowden.

On the Action of some Animal Poisons. *By* M. Fayè, *M.D., Professor in the University of Norway.*

On the Action of the Auriculo-Ventricular Valves of the Heart. *By* Dr. Gairdner.

The author had frequently found auriculo-ventricular regurgitant murmurs, which were not fully explained by the *post-mortem* appearances. He pointed out anatomical conditions of the valves at the time of their tension, which he believed have not been sufficiently attended to; and that these explained the occurrence in certain otherwise obscure cases of regurgitant murmurs without organic lesions of the valves or dilatation of the orifices.

On the Mortality from certain Diseases. *By* Dr. Gairdner.

The object of the author was to obtain a more accurate account of the causes of death, especially in our hospitals, than yet obtained by the reports afforded by those institutions. In the course of his remarks Dr. Gairdner commented upon the returns of the Registrar-General, and stated that for the purposes of medical science they were in many respects framed so as to mislead, from their referring only to a single cause of death in each case, whereas the real fatal issues of disease were usually very complex.

On the Oriental Bath. *By* Edward Haughton, *M.D. (Edinb.), M.R.C.S. Ed.*

Antiquarians inform us that some of the most ancient ruins in the world are those of hot-air baths; whilst hot-water baths (to lie down in) are so modern as to have been unknown to the Greeks. The former kind possesses many marked advantages over the latter, both in purifying the blood, and as a simple detergent; being, moreover, less liable to overheat the body; the evaporation from the surface being a safeguard in the case of hot-air which does not exist when a denser medium is employed. When the skin has been got to act well, soap and water are then employed to remove the impurities thus brought to the surface. The baths of the East are not only more salutary than those which we are familiar with, but are infinitely pleasanter; as the bath itself is a chamber permitting perfect freedom of motion. It is also of a social character; a kind of bathing dress being worn of sufficient size to permit persons of the same sex to meet together without embarrassment. This kind of bath is universally resorted to by Mahometans as a religious duty; indeed, on a rough calculation, it may be said to be employed by $\frac{1}{5}$th of the human race. No objection on the head of climate can be urged against this practice, as it is employed in so many and so *variable* regions; nor could it be used (as it is) by every class of society, if there were anything in its nature to prevent it from being self-supporting at a reasonable charge. It appears, moreover, that certain forms of disease (here very prevalent) are scarcely known at all in those countries, where the bath is in general use; and that it also possesses considerable curative efficacy, being capable of removing opium, nicotine, alcohol, and other poisons from the blood; so that it is not unreasonable to suppose, that if it were introduced into this country, a great sanitary revolution would take place. These circumstances render it worthy of the best attention of all reformers and philanthropists.

On the Physiological Relations of Albumen. *By* Professor Hayden, *M.D.*

The writer commenced with some preliminary observations tending to show that the elimination by the excernent glands of the body of certain of the staminal principles of the blood, was indicative of derangement in the normal proportion of its constituent elements, whether resulting from temporary indigestion or confirmed disease;

and proceeded: "It is well known that the 'elements of respiration' may be stored up in the body by a process of deposition in the form of fat, to meet the urgent demands involving a large expenditure of these elements, to which variation of external temperature and other circumstances occasionally expose the animal. Not so, however, the 'plastic elements of nutrition;' these are appropriated only as required for immediate use in the renovation of the tissues; and if from any cause one of them happen to be in excess in the blood, whether absolutely, as the direct result of indigestion, or relatively, by loss of some of the allied constituents, then a process which may be conveniently designated *elemental adjustment* is set up, by which the principle in excess continues to be discharged from the system till it attains the normal proportion relatively to the other staminal elements."

In proof of the existence of this self-adjusting power in the blood, the observation of Kaupp was mentioned, to the effect that the quantity of chloride of sodium excreted by the kidneys, usually observed a definite proportion to that taken by the animal; but if this salt be withheld for some time and then given in large quantity, the kidneys are found to eliminate *less* than the quantity taken: also that of Andral, "that the first effect of hæmorrhage on the constitution of the blood is a decrease of the corpuscles only; but if it (the hæmorrhage) be prolonged or repeated, the albumen and fibrine are found to have undergone a corresponding diminution." In such a case, it is asserted by Becquerel and Rodier that the equilibrium is not restored through the blood lost, in which the corpuscles and albumen observe a regular and equal ratio of decrease with each subsequent bleeding. Albumen is occasionally found in the urine of pregnancy, and may be accounted for on this hypothesis, by the loss of blood-corpuscles, often to the amount of 27 parts in 1000, experienced by such females who are peculiarly anæmic. An absolute or relative decrease of the fibrine, as in scurvy and plethora, will give rise to spontaneous hæmorrhage, by which the equilibrium is restored between the fibrine and globules. The marked pallor in Bright's disease indicates a loss of red corpuscles, amounting, according to the analyses of Becquerel and Rodier, to nearly 10 per cent. The albumen likewise undergoes a diminution, greatest towards the termination of the disease. In the chronic form of this disease the decrease of corpuscles and albumen was still more marked, whilst the fibrine had increased to a mean of 4·37 per thousand.

In order to test the correctness of the views here set forth in general terms, the following experiments were performed; the object was threefold, viz. 1st, to determine the effect produced on the urine by inducing an absolute or relative increase of albumen in the blood; 2ndly, the action of urea on the blood-corpuscles as exhibited by the microscope; and 3rdly, the proportion of albumen contained in the serous effusions of renal and cardiac dropsy respectively. With the first-mentioned object in view, blood was taken from living animals, the effect of which was a *decrease* in the proportion of corpuscles and a relative *increase* of the albumen of the circulating blood. An absolute increase of the albumen was produced by drawing a small quantity of blood from an animal, and then injecting into the vein an equal quantity of a solution of albumen of the temperature and specific gravity of blood-serum. After having been operated upon, the animal was placed under a wire crib on a concave zinc table, with an aperture in the bottom leading into a receiver, in which the urine was collected.

Experiment 1.—A rabbit, weighing $3\frac{1}{2}$ lbs., was fed on cabbage, milk and water; the urine passed next day was feebly alkaline, specific gravity 1020, and free of albumen: the animal was then bled to 6 drachms, and fed on fresh grass and warm milk; the urine examined next day presented the same reaction and specific gravity, but became distinctly opalescent by heat and nitric acid.

Experiment 2.—A dog, weighing 18lbs., was fed on milk and stirabout; urine neutral, specific gravity 1020, contained no albumen: the animal was bled to 8 ounces on the 18th August; on the 19th, the urine collected during the previous night was examined and found neutral, specific gravity 1030; it contained a trace of albumen. Examined again on the 20th, the urine was found alkaline; its specific gravity had fallen to 1020, still a trace of albumen. Aug. 21, specific gravity 1022; albumen as on yesterday. The quantity of blood taken in the experiments was determined by the estimate of Welker, according to which the total quantity in the body of an animal is equal to $\frac{1}{13}$th its weight.

When the quantity of albumen held in solution is very small, the microscope affords much aid in its detection. If a drop of the suspected liquid be placed on a slip of glass in the field of the microscope, and a drop of nitric acid be added, a cloud of minute vesicles will be observed to pass slowly over the field of view ; and if the line of advance of this cloud be closely observed, the suddenness with which the constituent vesicles start into view from an apparently structureless fluid, cannot fail to arrest attention. These minute bodies present a highly refractive margin, with a light centre, and an average diameter of $\frac{1}{10000}$th part of an inch.

Experiment 3.—A young dog, weighing 12lbs. 7oz., was next subjected to experiment. The urine collected before operating was free of albumen and alkaline, specific gravity 1005. Blood was now drawn from the jugular vein to the amount of 5 ounces, and into the aperture in the vessel was injected ℥ss of fresh dilute ov.-albumen having the temperature and density of blood-serum. Bread and warm milk were given as food, and ravenously eaten. The following day it was found that no urine had been passed in the interim ; the second day after (Aug. 27th), 4 ounces of urine were collected, neutral in reaction, of specific gravity 1030, and highly albumenous, being almost gelatinized by heat and nitric acid. The albumen was coagulated and collected by filtration, dried, pulverized, and freed from impurities by ether and boiling water, subsequently dried and incinerated; the total quantity of pure albumen thus obtained was 9 grains. In order to determine what proportion of this was due to the ov-albumen injected, and what, if any, to the ser-albumen discharged in consequence of the bleeding, I ascertained the amount of pure dried albumen yielded by half an ounce of the white of egg, and found it to be $72\frac{1}{2}$ grains.

I had expected, and probably would have found, had the operative part of the experiment been in all respects successful, a balance in favour of the albumen excreted in the urine, as compared with the quantity contained in half an ounce of the white of egg, but unfortunately, at the moment when the last portion of albumen was injected, and before a ligature could be applied to the open vessel, the dog struggled violently and caused a fresh loss of blood, with probably a more than proportionate loss of the albumen injected, as the bleeding occurred chiefly by regurgitation from the heart. Five ounces of urine were obtained from this dog on 28th August, but containing no trace of albumen.

With regard to the action of urea on the blood-corpuscles, when exposed for a few hours to a concentrated solution of urea, the corpuscles become tumid and many entirely disappear ; the action, however, is slow and feeble.

The proportion of albumen in the different dropsical effusions next engaged my attention. If the hypothesis be well-founded, namely, that albuminaria is the result of an effort of the blood to restore the equilibrium between its corpuscles and albumen by ridding itself of a portion of the latter, then we might not unreasonably expect to find the blood-serum effused coincidently into the cellular tissue and serous cavities, bearing evidence of the same tendency by containing an excess of albumen. With the view of determining this point by comparison between the fluids of renal and cardiac dropsy, I analysed the serum obtained by acupuncture from two cases of renal anasarca, and compared the results with those obtained by Andral from his analyses of the serum of cardiac dropsy. The proportion of albumen obtained by Andral ranged between 4 and 48 parts in a thousand ; in my two analyses the proportion was 12 and 24 per thousand respectively. I should desire, before coming to any definite conclusion on this point, to pursue this portion of the inquiry still further.

The inherent property of *quantitative adjustment* in the blood would appear to have reference mainly to nutrition, which requires as an essential condition for its healthy exercise, certain fixed mutual proportions between the constituent elements of the blood. The maintenance of the normal relative density of the serum and corpuscles is obviously subserved also by this property.

The appearance of albumen in the urine is either transitory or persistent. When transitory, it is produced either by an error of excess in the use of proteine substances, of which the blood seeks to relieve itself through the kidneys ; or by a state of congestion of these organs, in which the blood-serum transudes to walls of the renal capillaries and is discharged with the urine. When persistent, it is probably always the result of continued loss or solution of the blood-corpuscles, and produced by an

inherent self-regulating property in the blood, by which the normal relative proportion between its constituent elements is sought to be re-established.

In acute renal dropsy the *point de départ* in the blood-changes would appear to be loss of albumen; but in the chronic form of the disease attended with uræmia, the starting-point probably is solution of the corpuscles.

The loss of albumen experienced by the blood in Bright's disease would appear to be inversely proportioned to the quantity which appears in the urine, and probably in the dropsical effusion.

The quantity of fibrine in the blood is regulated in great part by that of the corpuscles, not by "adjustment," but in virtue of the causal relation subsisting between the disintegration of the one and the production of the other.

Diminution by *removal*, therefore, of the quantity of globules in the blood will not necessarily cause elimination of the fibrine, because it involves diminished production of the latter; but the converse of the proposition will not hold, as diminished proportion of fibrine, by whatever cause produced, may give rise to elimination of the blood-corpuscles in the form of hæmorrhage.

On certain Pathological Characters of the Blood Corpuscles. *By* J. P. Hennessy.

The author stated the results of his microscopical observations on healthy blood, and on inflamed blood. The result to which he directed particular attention was, that in inflamed blood the corpuscles were smaller and darker than in healthy blood. In corroboration of his views, he quoted the remarks of M. Donne, of Mr. Wharton Jones, Mr. Gulliver, and many others. Upon this change of size Mr. Hennessy founded a theory of inflammation; the increase of temperature, the occurrence of the buffy coat and the other phenomena being satisfactorily explained.

Dr. Lankester laid on the table a number of the Tables issued by the Committee for the Registration of Periodic Phenomena. These Tables were filled up, but he complained that every year persons took the tables, promising to fill them in, but failed to send them to the Committee.

On the Alternation of Generations and Parthenogenesis in Plants and Animals. *By* E. Lankester, *M.D., F.R.S.*

The author, after alluding to the phenomena of "Alternation" as described by Steenstrup in the Entozoa, Medusæ, and Sertularian polyps, and to the phenomena of Parthenogenesis, described by Owen and Von Siebold, concluded his paper as follows:—"If we turn now to the vegetable kingdom, we find perfectly analogous phenomena presenting themselves. In fact, the modifications of the reproductive function, which have recently excited so much surprise in the animal kingdom, are the normal forms of the function among plants. In the roots and branches of a tree we have a gigantic 'nurse,' and the buds are its progeny. Just as we find the same secondary products called 'gemmæ,' in animals either remaining adherent to their parent-stocks, as in the Sertularian and other zoophytes, or floating off, as in Hydra and many others, so we find the buds of plants remaining attached to the tree, or becoming separated from it. Just, too, as we find a different form assumed by the secondary offspring of the 'nurse,' as in the scolex-head of the cystic-worm, so we find in such cases as those presented by the 'bulbillus,' the 'bulb,' and the 'sporule,' different forms assumed by parts having the same relations in the plant as in the animal. So likewise in the plant we find a greater change of the secondary offspring taking place, when sexes are developed and flowers are produced, and the hermaphrodite flower, with its stamens and pistils, is the representative of the segments (proglottides) of the tape-worm, with its male and female apparatus in a common envelope. We may go yet further with our analogies in the vegetable kingdom. Here also we have numerous cases in which the germ-cell, the ovule, is produced, and developes within itself an embryo, quite independent of the influence of the sperm-cell, the pollen." The paper was illustrated by the following diagram:—

GENESIS.

HOMOGENESIS. (Reproductive force acting through similar cells.) It is represented in—	HETEROGENESIS. (Reproductive force acting through dissimilar cells, sperm-cells and germ-cells.) It is represented in—
A. Plants by Phytoids.	A. Plants by
1. Isophytoids.	1. Gynophytoids.
Buds.	Female flowers.
2. Allophytoids.	Pistillidia, &c.
Bulbilli.	2. Androphytoids.
Bulbs.	Male flowers.
Sporules, &c.	Antheridia, &c.
	3. Androgynophytoids.
	Hermaphrodite flowers.
B. Animals by Zooids.	B. In animals by—
1. Isozooids.	1. Gynozooids.
Gems, or buds.	Females.
2. Allozooids.	2. Androzooids.
Nurses (Steenstrup).	Males.
Agamozooids (Huxley).	3. Androgynozooids.
Virgin Aphides (Owen).	Hermaphrodites.
Agamic eggs (Lubbock).	
Drone Bees (Siebold).	

On the Flow of the Lacteal Fluid in the Mesentery of the Mouse. *By* JOSEPH LISTER, *F.R.C.S.E.*

The objects of the experiments were twofold—1st, to ascertain the character of the flow of the chyle under ordinary circumstances, which he believed had never yet been satisfactorily done; and 2ndly, to endeavour to throw some light upon the debated question, whether or not the lacteals were capable of absorbing solid matter in the form of granules visible to the human eye. In the first set of experiments, a mouse having been put under the influence of chloroform an hour or two after partaking of a full meal of bread and milk, the abdomen was laid open by a longitudinal median incision, and a fold of intestine drawn out gently so that it might lie on a plate of glass under the microscope, the exposed part being occasionally moistened with water of the temperature of 100° F. Under these circumstances, the lacteals were very readily visible as beautiful transparent beaded cords; the beads corresponding to the situations of the valves, which were seen to be standing open, while chyle-corpuscles moved on through the tubes with perfectly equable flow; as a rule equal to about a quarter of that at which the blood moves through the capillaries. These observations were frequently repeated, and always with the same result. Hence it was clear that the lacteals, though known to be muscular, and richly provided with valves, do not, in the mesentery at least, promote the flow of the chyle by contraction, rhythmical or otherwise; and that the source of the movement of the fluid is some cause in constant and steady operation. It was further observed that the chyle-corpuscles were, many of them, already of full size, although at so short a distance from the scene of absorption, proving the rapidity with which those corpuscles are elaborated.

The other set of experiments were performed in the same way, except that some coloured material, generally indigo, was mixed with the bread and milk. The animals took the mixture readily, and it passed freely along the intestines, but no indigo particles were ever seen in the chyle, although, had it been absorbed in the solid form, it would have been detected with the utmost facility within the lacteals. It might be supposed that the colouring matter had acted as a poison, and paralysed the function of absorption; but there was no appearance of this, the chyle flowing just as rapidly as when the mice were fed with simple bread and milk. These facts, though not perhaps absolutely conclusive, seemed to throw great doubt on the possibility of absorption of solid matter by the lacteals.

On the Importance of introducing a New and Uniform Standard of Micrometric Measurement. By Professor Lyons.

The author alluded to the great difficulties experienced by observers in enumerating, recording, and remembering the various kinds of measures now in use in these countries and on the Continent, portions of the English and French inch and line, and decimal parts of the French millimetre. The high figure in the denominator and the number of decimal places are exceedingly cumbrous. He (Dr. Lyons) would propose that some definite micrometric integer should be assumed, being a determinate part of unity. He proposed that this measure should be denominated a Microline. He did not mean definitely to bind himself to the adoption of any particular standard, but would propose provisionally that the one ten-thousandth part of the English inch should be assumed and denominated the standard Microline *pro tem.* The size of microscopic objects could thus be recorded simply, by saying they were one, two, three, or more Microlines in diameter. He would have his hearers bear in mind the present tendency of scientific men towards a decimal system. For his own part, he would prefer to assume as the standard Microline, some minute subdivision of the French decimal scale.

Professor Lyons exhibited an instrument for the local application of chloroform, the invention of Dr. Hardy of Dublin, which for simplicity and effectiveness he thought contrasted very favourably with any similar instrument he had yet seen.

On the Valvular Apparatus connected with the Vascular System of certain Abdominal Viscera. By Robert M'Donnell, *M.D.*

A series of drawings were exhibited, showing the anatomical structure and arrangement of the valves situated at or near the point where the renal veins open into the vena cava ascendens in various animals as well as man.

The author having spoken also of the beautiful valvular structures which in the lower animals are so constantly found guarding, more or less, completely the mouths of the hepatic veins, detailed some experiments performed by him, which seem to show not only an anatomical but physical grounds that these valves cannot act otherwise than in preventing, or at least checking any regurgitation of venous blood into the vessels thus guarded: on these grounds he was opposed to the so-called "Hepatico-renal" circulation.

Dr. Millingen introduced to the Section a method he had adopted of preserving the vaccine virus in glycerine.

On the Connexion between Atmospheric Vicissitudes and Epidemic Diseases. By Dr. Poznanski.

The author exhibited an instrument for measuring the force and number of the pulsations of the arteries.

Note on Electric Fishes. By Sir J. Richardson, *C.B., M.D., LL.D., F.R.S.*

The author stated that there were not less than eleven genera of fishes known that had the power of giving electric shocks. There was one peculiarity in all these fishes, and that was the absence of scales. In every one of them an apparatus had been discovered which consisted of a series of galvanic cells put in action by a powerful system of nerves. He read extracts from a letter from Dr. Baikie, now engaged in exploring the Niger, in which that gentleman stated he had met with an electric fish in Fernando Po, and which he believed was identical with the *Malapterurus*, which had been described by Dr. Wilson, from the coast of Old Calabar. The natives called this fish the Tremble-fish.

On the Employment of the Living Electric Fishes as Medical Shock-Machines. By Professor G. Wilson.

The author stated, that in prosecuting researches into the early history of the

electric machine, he did not contemplate going further back than the seventeenth century, or commencing with any earlier instrument than Otto Guericke's sulphur globe of 1670. His attention, however, had been incidentally directed to the employment of the living torpedo as a remedial agent by the ancient Greek and Roman physicians, and he now felt satisfied that a living electric fish was alike the earliest and the most familiar electric instrument employed by mankind. In proof of the antiquity of the practice, he adduced the testimony of Galen, Dioscorides, Scribonius, and Asclepiades, whose works proved that the shock of the torpedo had been used as a remedy in paralytic and neuralgic affections before the Christian era. A still higher antiquity had been conjecturally claimed for the electric Silurus, or Malapterurus of the Nile, on the supposition that its Arabic name, *raad*, signifies thunder-fish, and implies a very ancient recognition of the identity in nature of the shock-giving power and the lightning force; but the best Arabic scholars have pointed out that the words for thunder (*raad*) and for the electric fish (*raa'ád*) are different, and that the latter signifies the "causer of trembling" or "convulser"; so that there are no grounds for imputing to the ancient Egyptians, or even to the Arabs, the identification of Silurus-power with the electric force. In proof of the generality of the practice of employing the living zoo-electric machine at the present day, the author referred to the remedial application of the torpedo by the Abyssinians, to that of the Gymnotus by the South American Indians, and to that of the recently-discovered electric fish (*Malapterurus Beninensis*) by the dwellers on the Old Calabar River, which, strictly speaking, flows into the Bight of Biafra, but by a looser geographical interpretation is held to enter the Bight of Benin. The native Calabar women are in the practice of keeping one or more of the fishes in a basin of water, and bathing their children in it daily, with a view to strengthen them by the shocks which they receive. These shocks are certainly powerful, for living specimens of the Calabar fish are at present in Edinburgh, and a single one gives a shock to the hand reaching to the elbow or even to the shoulder. The usages referred to appear to have prevailed among the nations following them from time immemorial, so that they furnish proof of the antiquity as well as of the generality of the practice under notice.

The author concluded by directing the attention of naturalists to the probability of additional kinds of electrical fish being discovered, and to the importance of ascertaining what the views of the natives familiar with them are in reference to the source of their power and to their therapeutic employment.

Miscellaneous.

On the Functions of the Human Ear. By Professor H. Carlile, *M.D.*

Dr. Carlile made some observations on the manner in which sounds are reflected by the auricle and external meatus of the human ear, and so caused to fall on the membrana tympani. He showed that after reflexion from the surface of the concha, and from a cavity formed by the inner surface of the tragus, they are received upon a third concave surface, or reflector, situated at the upper and back part of the tube, where the cartilaginous joins the osseous portion of the meatus, whence they are transmitted, some directly to the surface of the membrana tympani, falling upon it obliquely, and others to the outer and lower part of the tube, reflected from which they fall on the membrana tympani nearly at right angles. The first three reflecting surfaces are the chief seats of the sebaceous glands, those appertaining to the second and third surfaces secreting the substance called the cerumen, or wax, of the ear, distinguished by its yellow colour and bitterness. This bitter secretion is very probably, as it is generally described, a preventive of the ingress of insects, as these are not found to enter the tube of the ear even when persons sleep upon the ground in places swarming with insects, such as earwigs, &c.; but it is very likely that these sebaceous secretions also serve the purpose of a varnish, which, being spread over the reflecting surfaces, produces a smoothness, and a regularity of curve, favourable to the transmission by reflexion of the pulses of sound in their passage to the membrana tympani. It is highly probable that slight deafnesses, such as are occasion-

ally the result of exposure to cold, are produced by trifling alterations in the quantity or quality of this secretion, which, when very abundant, is known to cause nearly complete incapacity of hearing, until the accumulation be removed. In this respect the ear seems to possess an analogy with the other organs of sense, the skin, the tongue, the nose, and the eye, in all of which the normal condition of the surface secretions is necessary for the due performance of the specific function of the organ. Dr. Carlile also called attention to the form of the external ear in some species of the *Vespertilionidæ*, more especially in the *Plecotus auritus*. In this animal the external ear consists of a large posterior auricle, almost as long as the body of the creature, and a small anterior auricle, nearly symmetrical with the larger, the tube of the ear opening at the lower part of these appendages, in front of the larger, and behind the smaller. The smaller auricle is generally regarded as an operculum, which prevents the entrance, into the tube of the ear, of the air, when the animal flies with rapidity in pursuit of its prey or against the wind; but more probably, like the tragus, its homologue in the human ear, it serves as a reflector, receiving on its back or inner surface many rays of sound, sent by reflexion from the front or hollow surface of the larger auricle, and reflecting them again to the same surface, whence they are transmitted, either by one reflexion or by several, between the opposed surfaces of the large and small auricles, to the tube of the ear, in order to reach the membrana tympani. Were it not for this provision, many rays of sound, after a first reflexion from the surface of the larger auricle, would pass into the air, and be altogether lost. The large size of the cochlea in some Vespertilionidæ, found in connexion with the great expansion of the auricle, would seem adverse to the opinion that the cochlea is the portion of the internal ear specially adapted to receive sounds conveyed by conduction through the solid parts of the head, the great reflecting power of the auricles being one of the distinguishing characteristics of the organ.

A "Register of Periodical Phenomena at South Lincolnshire," and "Register of Periodical Phenomena at Llangefelach, Glamorganshire," were presented.

GEOGRAPHY AND ETHNOLOGY.

On the Ethnological and Physical Characters of the Negro variety of mankind. By ANTOINE D'ABBADIE, *Correspondent of the French Institute.*

THE following statements were founded chiefly on the author's own observations collected during a ten years' stay in Eastern Ethiopia.

The settlement of the negroes in Africa was effected by a stream of immigration flowing from east to west. The negro tribes who live now in the most easterly parts have the largest facial angle, the greatest amount of intelligence, and can be referred, by slow and almost imperceptible gradations of form and colour, to the red races of Ethiopia, which all authors have until now agreed in referring to the Caucasian stock. From his total inability to decide whether several individuals of the Doggo, Barya, and Nara tribes belonged to red or to negro origin, he has been forced to conclude that all future controversies on the creation of negro varieties of mankind must take into account the fact of a *gradual* formation of the black variety, or at least must explain, in the uncalled-for hypothesis of a separate negro creation, how tribes living in continual war with their neighbours, have amongst themselves, and spontaneously as it would seem, several individuals who must be referred to a variety alike alien to the majority of their relations and to that of their fellow-countrymen.

The author proceeded to quote several facts drawn from tribes living at opposite extremities of Ethiopia and separated by an extent of country equal to the breadth of France. It is inferred from these facts, that in tropical Africa the skin of man is blackened when the chief food is not animal, but vegetable. Numerous direct observations prove that the air of Ethiopia differs from that of Europe by some very

remarkable properties, which *may* have likewise a hitherto unrecognized effect in blackening the human skin. Finally, the traveller quoted several cases where the skin was notoriously blackened, with or without apparent malady, in the *same* person living in the very peculiar Ethiopian climate. This latter fact is generally believed and asserted by the Ethiopians themselves.

On the Anomalous Period of the Rising of the Niger. *By* HENRY BARTH, *LL.D.*

The Human Hand, an Index of Mental Development. *By* RICHARD BEAMISH, *F.R.S.*

The author first alludes to the labours of Lavater, Gall, Sir Charles Bell, Earl Gustav Carus, and others, who have sought to demonstrate the value of the symbolical system, dwelling more at length on those of Georg Meissner, as furnishing, in his 'Anatomie und Physiologie der Haut,' the fullest demonstration of the nerve of touch as contradistinguished from that of feeling; and of D'Arpentigny, as offering, in his 'Chirognomie ou l'art de reconnaitre les Tendances de la Main,' the first definite and practical illustrations of the value of the hand in ethnological inquiries.

The author then proceeds to consider the several portions of the hand—the palm as indicative of temperament; the development of the thumb as significant of power; and the form of the fingers as expressive of social and intellectual character; reference being made to numerous tracings of the hands of individuals of different nations, whereby the great importance of the study of the hand by the ethnologist was inferred.

The necessity for a more extended knowledge of the religious and social instincts of nations was strongly urged, and the effects of ignorance in this department of science illustrated by reference to our systems of government both at home and abroad, in Ireland, and in India, where the nationalities of the people had been equally disregarded, and as a consequence, equally productive of results not only disappointing, but disastrous.

On the Physical Characters of the Ancient and Modern Germans. *By* JOHN BEDDOE, *M.D.*

All accounts of the physical character of the ancient Germans agree in representing them as a very light-complexioned people, having hair redder or yellower than that of the Gauls, themselves considered as fair by the Italians. Niebuhr, Bunsen and Prichard, however, agree in thinking that their descendants, as a rule, do not answer to these descriptions, and have to a great extent ceased to be the xanthous race they were in the time of Tacitus. I am disposed, however, to doubt whether the differences in complexion between the Italians and the most pure-blooded Germans were any more marked in that age than they are at present. There are reasons for not taking too literally Tacitus' statements as to the remarkable uniformity of complexion in the ancient Germans: ξανθὸς and *flavus*, as applied to the colour of hair, probably meant chestnut or light brown rather than bright yellow; πυῤῥὸς, which means literally "flame-coloured," and *rutilus*, an epithet often applied to gold, may have included bright yellow as well as what we call red. The use of soap as a cosmetic by both Gauls and Germans had probably a great effect on the colour of the hair. Observe the light hue of the locks of Venetian ladies in the portraits of the 16th century, though their eyes, and the eyes and hair of their spouses, are represented as dark. This light colour is known to have been produced by the use of an alkaline ley.

In order to ascertain with accuracy some of the physical characters of the modern Germans, I have made observations in most parts of their country, and have noted the colour of the hair and eyes—in Holland, in 1133 individuals; in Belgium, in 4023; in North-Western Germany, in 2545; in Prussia, Saxony, &c., in 1220; at Vienna, in 1807; and in other parts of Austria, in 1659: I have seen but very few natives of Swabia and Bavaria, and not many Swiss.

The general result of these investigations is, that hair of a very strongly red hue is in scarcely any of the districts I have visited so common as it is in many parts of Scotland, and even of Ireland. The exceptions to this statement are two somewhat remarkable ones: the first is that of the peasantry about Cologne and Dusseldorf, whose ancestors, whether Sicambri or other Franks, may have had much to do with originating in the minds of their near neighbours, the Roman colonists, ideas relative to the German complexion and physiognomy. The other is that of the peasantry to the west of Eisenach.

Red hair is decidedly uncommon in Friesland, and somewhat so in Holland and Flanders; but blond hair of various shades, from flaxen and light brown to yellow, and even pale golden verging on red, prevails in all parts where the true Teutonic blood can well be supposed pure, including all that country between the Rhine and Elbe which is considered by Dr. Latham to be the homeland of the race. The same may be said of several districts in which we have reason to know that the Germans established numerous colonies. The proportion of light to dark eyes varies considerably: it is very large in Groningen, and small in Flanders, where, as in most parts of Germany, and in some of the Saxon districts of Britain, the combination of hazel or brown eyes with light hair is common. I found the Frisians a remarkably comely people, tall and well-made, with oval crania and faces, regular features, and noses of good length, straight or very slightly arched: the eyes are generally light blue or light grey and well-opened; the hair is, I think, much more often flaxen or light brown than strongly yellow. The Westphalian Saxons seemed to me shorter in stature; with heads shorter, though still oval, and faces broader and heavier, and hair more often inclined to red. Beyond the Elbe and Saale, where Slavish blood assuredly predominates over German, the prevailing type changes accordingly; dark and even black hair become common; the head is often of the Slavonic form, short and broad, especially behind the ears, and flattened at the back. The Upper Austrians look like true Germans, but I have seen natives of the Alpine valleys who had narrow square foreheads, prominent supra-orbital ridges, dark grey eyes and blackish hair, and who altogether so much resembled one of the common Irish types as to call to mind the ancient Celts of Noricum. The Lower Austrians, whatever else they may be, have not the form or complexion of Germans. Their heads sometimes present the Slavish, sometimes even the Turanian (Avar?) type; and they are generally dark-haired. The Styrians are a mixed people, and apparently in part Celtic. In the Thuringerwald, at Rühla, near Eisenach, and not far from the fair-haired Hessians, I found a peculiar people of very dark complexion. The domain of the German type extends thence across the Rhine; but on entering the Walloon country, which surrounds Liege, a remarkable change is observable: the people are distinguishable from their Teutonic neighbours by dark, often black hair, gaunt angular forms, square foreheads and narrow pointed chins; in fact, they have the characters assigned by W. F. Edwards to the Cimbrian race*.

In many cities, as will be observed in the following Table, which exhibit in a form suitable for comparison some of my data for the colours of eyes and hair, the population is darker than in the surrounding rural districts. It might be wrong to conclude from these facts that a city life, continued generation after generation, exercises a modifying influence on the colours: for this difference is not universal even in Germany; it is greatest in Cologne, a Roman colony. The Germans being fairer than almost any other people, foreign immigration almost necessarily implies darkening, and such immigration takes place into cities almost exclusively. Lastly, I have found that at Liege, and in some parts of Italy, where the foreign element is likely to have been xanthous, the peasantry are darker than the urban population.

On the whole, I conclude that the Germans were in the time of the Romans a people fairer than the Gauls, and very strikingly fairer than the Romans and other southern Europeans; that their hair, however, was probably often light brown or flaxen, and not always red or even yellow; and that this description applies at the present day to such of their descendants as are likely to have preserved their blood tolerably pure.

* Sur les caractères physiologiques de la race humaine.

Table

Table exhibiting the proportions (per 1000) of the different colours of Eyes and Hair.

		Eyes Light. Hair.					Eyes Neutral. Hair.					Eyes Dark. Hair.				
	No. of obser-vations.	Red.	Fair.	Brown.	Dark.	Black.	Red.	Fair.	Brown.	Dark.	Black.	Red.	Fair.	Brown.	Dark.	Black.
Groningen	100	15	415	345	40	5	...	5	45	10	...	10	...	40	70	...
East Friesland	330	15	340	379	59	1	11	11	27	15	...	3	7	79	53	...
West Friesland	127	...	288	484	39	...	...	16	63	...	...	...	16	39	55	...
Münster peasants	150	30	307	323	60	...	3	43	40	20	...		13	70	80	3
Brunswick peasants	130	38	289	335	50	4	...	22	69	23	...	...	8	85	77	...
Cologne&Dusseldorf peasants	200	60	257	255	65	7	10	35	35	20	...	...	15	107	125	2
Brunswick city	130	31	208	289	65	...	15	38	100	19	4	8	23	96	104	...
Munster city	150	17	227	300	63	...	7	40	77	23	...	...	13	117	103	10
Rotterdam	250	20	268	321	80	2	...	10	62	16	2	4	20	62	121	8
Antwerp peasants	200	17	175	325	45	2	...	27	112	40	...	...	20	120	110	5
Eisenach peasants	150	57	189	311	99	7	13	13	73	60	...	3	10	56	83	27
Amsterdam	250	12	148	382	100	...	...	22	62	54	2	4	4	80	128	2
Antwerp city	700	11	126	368	66	...	...	14	76	33	...	1	15	120	171	13
Dresden peasantry	250	8	114	344	96	6	2	38	62	30	...	4	16	94	170	16
Dresden city	212	23	143	308	76	...	2	18	68	56	...	...	2	87	192	25
Berlin city	500	14	121	339	103	3	2	14	79	52	3	4	16	71	141	36
Cologne and Aachen	600	40	134	266	95	9	6	14	57	42	9	3	12	83	193	45
Bruges	500	4	93	326	59	2	3	10	74	51	2	...	5	131	230	10
Prague peasants	200	17	120	325	97	7	5	10	88	62	...	...	2	70	160	35
Vienna natives of city	99	25	116	212	141	...	...	20	76	66	...	...	...	66	212	66
Liege city	350	11	86	273	120	13	...	14	66	66	11	...	6	70	223	41
Liege peasants	120	...	62	254	125	8	...	17	58	54	12	...	17	92	229	71
Lower Austria	250	10	112	228	70	8	4	10	66	112	16	...	...	56	252	60
Rühla	95	...	37	247	126	...	...	...	94	84	11	11	...	79	273	37

Ethnological and Antiquarian Researches in New Granada, Quito and Peru, with Observations on the Pre-Incareal, Incareal, and the Monuments of neighbouring Nations in Peru. By W. BOLLAERT, *F.R.G.S., Corresponding Member of the University of Chile, &c.*

The author says, when passing through the West Indies, that one looks in vain for even a specimen of the aboriginal inhabitant of the Antilles, once so populous; one only sees a few whites, the population being principally negroes, and the numberless mixtures of white and black, but the natives have long since been exterminated by the ruthless Spanish invader.

The coast of New Granada was visited, the tropical vegetation of which is wonderful, and where the "Victoria Regia" was found in some places in such abundance in the rivers as to be a troublesome weed. A few scattered remnants of Indian tribes are met with on the coast, but in the interior they are more numerous.

The principal Indian nation of New Granada is generally called Muysea: this word means a man, but Chibeha is the proper term for the nation.

Some modern writers state that Quetzalcoatl, the legislator of Mexico, Bochiea of Bogota, and Maneo Capae, were Buddhist priests; the result of Mr. Bollaert's inquiries in those countries, leads him to set such down as mere *ideas*, and to have no foundation whatever.

The author crossed the Isthmus and saw some of the Darien Indians at Panama, rather fine-looking people; they went about almost naked, and the general impression is that the white man is not safe in their wilds. There is now a railroad across the Isthmus. The scheme of a ship canal for the present is abandoned; most things are possible, but a ship canal through the Isthmus is very *improbable*.

The population of New Granada is 2,363,000, composed of Whites, Cuarterones, Mestyes, Indians, civilized and savage, Mulattos, Zambos, and Negroes.

The author expresses surprise that monuments of more ancient nations than those conquered by the Spaniards have not been discovered in this country and in the same abundance as have been found in Mexico, Yucatan, and Cheapos, and adds, perhaps the dense tropical forests cover such remains, and are awaiting the footsteps of the antiquarian explorer.

The Chibehas (Muyseas) had a species of calander, and had necessarily advanced in a peculiar species of civilization, but then there is but little left to throw any light on their architecture. They buried in tombs, with various precious ornaments, including objects in gold and emeralds. Their places of adoration were lakes and rivers, into which were thrown their offerings.

Scattered about the country stone ruins exist, supposed to be the work of natives anterior to the Chibehas. Near Lieva is one of these spots, and called "Little Hell;" and the "Devil's Cushions" are stone columns lying on the ground; also a great stone table of sacrifice. Caves full of mummies are often met with; in these crania of more ancient nations than the Chibehas may be found.

Quito is an interesting portion of the New World, celebrated by being under the equator, its capital being 10,000 feet above the sea; for the great elevation of its volcanic mountains, including Chimborazo; and as having been the seat of a very ancient civilization long before it was conquered by the Caras or by the Incas of Peru.

In earlier times the country was governed by Quitus and conquered by the Caras. The Caras had taken possession of the coast about A.D. 800, and their chiefs were called Scyris, or lords of all. These Caras may have separated at a very early date from the Chimus of Trujello, or from the great Chineha family.

The Caras made their way to Quito by the river Esmeraldas about A.D. 1000; they adored the sun and moon, and were less barbarous than the Quitus; they clothed in skins, woven cloths of wool and cotton, and their year was regulated by the solstices; they are said to have had twelve pillars round their temple to the Sun, which served as gnomons. Although the Scyris adored the sun, they did not, as the Peruvians, call themselves "Children of the Sun." Their architecture has not so far advanced as the Peruvian. A wreath of feathers was worn by all who bore arms; the Scyri added to their wreath or crown of feathers, a large emerald.

Instead of the Peruvian quiper, they had pieces of wood, clay, stones of various sizes, colours and forms, by which was expressed principal occurrences, these being kept in compartments in their temples, tombs, and dwellings.

According to the reading of the coloured stones, 700 years is given by some for the reigns of eighteen or nineteen Scyris ; other readers give fifteen Scyris and 500 years up to the death of Cacha Duchicela, who was conquered by Huayna Capae, the Peruvian Inca.

The eighth Scyri conquered towards the south, making inroads upon the Puruhás of Liribamba.

By the death of the eleventh Scyri, about A.D. 1300, the male line of the Scyris was extinguished, when Toa, his daughter, was declared the successor; she married Duchicela, the eldest son of Condorazo, chief of the Puruhás, who reigned seventy years ; was succeeded by his son Antachi, the thirteenth Scyri, and died about A.D. 1370. Guallca, his eldest son, being of a bad disposition, his brother Hualcopo was put in his place, who died about 1463, leaving his kingdom to Cacha, the fifteenth Scyri, leaving an only daughter, Paccha, who succeeded him.

Huayna Capae, twelfth Inca of Peru, went against Quito in 1475 ; Cacha was mortally wounded, when his daughter Paccha was declared the Scyri. Huayna Capae, however, made overtures of marriage to Paccha, who was then twenty years of age, and by the law of Quito, whosoever she married could reign with her. Paccha consented, Atahualpa being her first son. Huayno Capac reigned thirty years over Quito, and at his death he gave the kingdom of Quito to his son Atahualpa, the empire of Peru descending to Huasca.

According to some, the natives of Quito called the supreme power *Con*: that Pachacamac was the son of *Con*. A temple was built on the coast of Peru to Pachacamac, where he was worshiped as the invisible God ; it would seem, however, that the first Inca taught his people that the Sun was the Supreme Power, and that Con and Pachacamac were his offspring ; also that he the Inca was a child of the Sun.

Under the 9th Inca, the country of Curysmancun, whose capital was at Pachacamac, was conquered by the Peruvians, when the Incareal theology was in danger from the purer one of Pachacamac; however, it was arranged that Pachacamac should retain his temples, and that others should be built to the Sun.

Peru.—Mr. Bollaert states, that in 1852 he communicated to the Ethnological Society a paper on the Incas and Inchans of Peru, noticing principally some points in early Peruvian history, and opposing the ideas of such writers as Ranking, who have given as their opinion, that the Peruvians had an Asiatic origin in the thirteenth century, that Manco Capae was the son of Glengis Khan ! and that the term Inga comes from the Mongol word Ungut ! ! The author also noticed that the dynasty of the Incas was rather modern, and that they had probably built some of their cities upon the ruins of those of more ancient nations, and adverted to those curious remains, the " Pintados," or Indian Pictography, observed by him in 1827 in Tarapaca. In 1853 Mr. Bollaert again visited South America, and extended his observations.

Adverting to the history, &c. of the aborigines south of Panama, Puná, and Tumbez, he dwells somewhat upon the history and remains met with at Trujello, the land of the ancient Chimus. During the time of the Inca Pachacuter, there reigned in this part of the country the chief Chimu-Canchu : the Inca Jupanqui made successful war upon this nation, which had to abandon the worship of idols and follow that of the Sun. The Chimu ruins are very extensive, the architecture and ornaments simple and elegant. Here then we have the ruins of a nation nearly as powerful as that of the Incas : there are also here Incareal remains. The Chimu Huacas or tombs have yielded, amongst other things, many rich ornaments in gold and silver. The author has deposited in the British Museum, with other pieces of pottery, a fine specimen of art, a vase forming the head of an Inca, having the lobes of the ears enlarged and known as an " Orejon*."

* Mr. Farris, long resident in this region, has just returned with a fine collection of antiquities, principally from Trujello.

The author enters into details of various collections of ruins in the north of Peru, not of Incareal origin, such as those of Cuelap, Huanuco, Patuelca, Pachacamac, &c. He also gives some particulars of the tombs of Cañete, anciently called the beautiful valleys of the Guarcu, which formed the state of the Chuqui-Mancu. The Chincha islands take their name from the ancient great Chincha nation of the coast, and it is supposed that there is guano only for ten years if it is taken away in such quantities as at present. At Arica, in 18° S., are many Huacas or tombs containing mummies, pottery, and various other curiosities. A cave is also described as existing in the Mirro or headland of Arica.

Mr. Bollaert was some time in the province of Tarapacá, famed for the existence there of inexhaustible quantities of nitrate of soda, about 50,000 tons of which are annually exported. A new mineral of boracic acid has lately been met with there. The celebrated silver mines of Huantajaya are in this province; copper exists in large quantities as well as other metals.

On the arid hills and mountains of the province of Tarapacá, Mr. Bollaert discovered the "Pintados," or ancient Indian Pictography. The figures are of large size, produced by taking away the loose dark pieces of stone in outline from the surface of the mountain. This peculiar species of Pictography he at first considered to have been done by the ancient as well as by the present Indians for amusement, but his recent researches show that they are Huacas or sacred spots, some of them being ancient burial-places. 1, called "Las Rayas," is laid out as if for a garden, with a large double circle in the centre, the paths rendered hard by the feet of people: religious ceremonies may have been performed here. 2 is composed of oblong figures. 3. A large double circle and oblong figures. 4. Irregular designs, figures of Indians, puma and llama. 5 is the most interesting, made up of compartments; in one of these was found an ancient grave containing the body of a female in a dress of feathers. The "White Horse," near Oldbury Castle in Wilts, is of this sort of "Pintados."

Near to the rich copper deposit in the Andes of Yabricoya, an interesting monument was fallen in with in the Pampa del Leon. Here is a large isolated block of granite covered with old Indian sculptures. The centre group is a man wrestling with a puma; there are also figures of llamas, guanacos, circles, serpents, &c. These figures have been picked out by a pointed instrument—say of hard brass.

Mr. Bollaert concludes by referring to the many ancient monuments existing in Peru, separating the Incareal from those of neighbouring and more ancient nations, assisting at least, with the labours of others, in the collecting of materials for the ancient history of Peru.

He examined the coal mines of Chile, and paid a second visit to Arauco. The Chilian government have it in contemplation to colonize that part of Chile; some think this may be done amicably, whilst others foresee, should such be attempted, a sanguinary war would result. Mr. Bollaert saw some of the Araucanos; they looked a superior race, and as if they would resist inroads into their lovely valleys filled with cattle and horses, and studded with the magnificent Araucaria, yielding them abundance of nuts forming their bread.

On the Routes of Communication between England and India. By Major-General Chesney, *R.A., D.C.L., F.R.S.*

The importance of a rapid communication with India is now an admitted fact by the whole of Europe. In reality it should have been so considered in past times, nor can it ever be otherwise so long as India remains a dependency of Great Britain. Since I had the honour of addressing the Section on this subject at Belfast, in 1852, the question of our communication with India by the line of the Euphrates has taken a much higher position than it then occupied in public attention. But before going on to the few remarks which I wish to make to you on this subject, I should like to point out to you the various existing and proposed lines of route to India, in order that you may have clearly before your mind what it is that I am anxious to accomplish by this Euphrates route of which you have so often heard. You all know our long sea line to India round the Cape, as well as the existing line by the Red Sea

and Aden to Kurrachee and Calcutta. The line proposed by Sir Rowland Macdonald Stevenson, and which is apparently the one preferred by Lord Palmerston, passes over the Balkan, the Taurus and other mountain ranges quite regardless of engineering difficulties. But if a direct line be drawn along the globe from London to Bombay or Kurrachee, it exactly takes in the route by the Valley of the Euphrates; consequently this portion of the line has necessarily formed a part of all the various projects that have been advanced with a view to facilitating and shortening our communication with India, with one exception, brought to my notice in a paper read last year at Cheltenham, which is supposed to go from Acre across the desert to Bussorah. The distance by the two overland routes are as follows:—

	English miles.
From London to the entrance of the Red Sea	4372½
From the entrance of the Red Sea to Kurrachee, which will, no doubt, become the great port of India in place of Bombay	1705
Total	6087½
London to the entrance of the Persian Gulf	4271
From the entrance of the Persian Gulf to Kurrachee	702
Total	4973

the difference in favour of the Euphrates Valley being 1104½ miles. The great gain, therefore, is from the entrance of the Red Sea and Persian Gulf onward. From the Red Sea to Kurrachee we have 1705 English miles; whilst we have only 702 from the head of the Persian Gulf to the same port, or less than one-half. In the one case we have the monsoon right ahead towards Aden; in the other it is nearly abeam to Ormuz—I need scarcely add, a difficult and dangerous navigation in the one case, and a perfectly safe one in the other. The completion of the proposed arrangements would enable us to get over this distance and carry mails and passengers from London to Kurrachee in thirteen days and a half, or less than half the time at present occupied in the transit by the Red Sea; while, by laying down an electric telegraph line by this route, we may, in eighteen or twenty hours, be assured of the welfare of some friend or relative in a distant part of India, whose fate is now a matter of uncertainty and anxiety. I should just point out to you also that the proposed railway will form a chain of communication with those lines up the valley of the Indus, &c., now in progress of completion in India, and will thus give us as direct a route as can be had between London and Lahore. But the rapidity of rail and electric communication forms but a small portion of the benefits which, in a political, military, commercial, and social point of view, will result from opening up the Euphrates Valley route to India. No country possesses associations of such deep and historical interest as this. We have here the first seat of mankind—the sites of the four primæval cities of the Bible—the empires of Cyrus the Great, Cyrus the Younger, and of the great follower of his steps, Alexander, whose conquests and unparalleled marches of 19,020 miles (according to a careful calculation which I have made), laid the foundation of that connexion of the East with the West which is now under consideration. The Romans also were alive to the great importance of this territory; for after the empire of Seleucus had passed away, we read of the attempt of Crassus to conquer the country 53 years B.C., and of the expedition of Trajan A.D. 106. Julian the Apostate followed in the steps of Trajan, A.D. 361. He built a fleet on the banks of the Euphrates, descended the river, and, according to Gibbon, encountered there a most terrific hurricane at a spot answering to the present El Kaim, above Anah; and it is remarkable that it was apparently nearly at the same spot that the expedition which I had the honour of commanding was visited by a similar and equally fearful hurricane in May 1836. From the period of Julian, A.D. 363, we have no record of any great military expedition in connexion with Western Asia until Napoleon conceived the idea in 1809 of transporting a force down the Euphrates with a view to the invasion of India. All his calculations and arrangements were made for

this end. His troops were to have been transported on rafts, constructed of timber cut down in the vicinity and on the banks of the river and sea coast. With a little of his daring we might do the same at this moment, and with much greater facility. There have been various proposals at different times for opening a communication with India by the Euphrates Valley. That which took the most practical shape was elaborated by Lieutenant Campbell, then of the Royal Engineers, in 1843. His proposal and map were in all essential points identical with those more recently proposed by the great engineer, Sir R. Macdonald Stevenson. These and many other subsequent proposals, both French and English, have all now become merged in the company of which Mr. Andrews is Chairman, and Sir John MacNeill, a man well-known among you, Engineer-in-Chief. I was induced last year to proceed to Constantinople to obtain the Sultan's firman, and make all preliminary arrangements for the proposed line to India; and I afterwards proceeded, accompanied by Sir John MacNeill, C.E., and two assistant engineers, to examine carefully the coast of Asia Minor, where the Taurus touches the sea, in the hope of finding a practicable valley for a future line through that country, and then proceeded to examine the coast for a good harbour. That of Alexandretta did not promise to answer, on account of its mountains, impassable for a railway; and the ancient harbour of Seleucia was also condemned as not affording sufficient depth of water. But on the southern side of the Bay of Antioch, a spot was selected by Sir John MacNeill admirably adapted to form a safe and commodious harbour of refuge. It will be capable of receiving second-rate line-of-battle ships, and will be as good as, or superior to, the harbour of Kingstown. The spot chosen is three miles south of the river Orontes, and six miles east of the old harbour of Seleucia. The harbour is proposed to be formed by running out a breakwater on the south side of the small natural harbour, which is a perfectly safe and secure landing-place for boats, with good holding-ground; so that vessels taking out materials for the construction of the railway could anchor in safety off this landing-place. Stone of the finest quality abounds close to the point where the breakwater will abut on the land, and can be quarried also to any extent in the immediate neighbourhood. It is proposed to construct about 1000 feet of the breakwater in the first instance, and to complete each portion as the work advances, so as to afford shelter and landing wharfs within the first year or eighteen months, which will enable vessels drawing 20 feet of water to lie in safety during the winter months, if required to do so; and within six months from the commencement of the work a landing-place can be formed, and perfect shelter for boats, at an expense of £20,000. The harbour, when completed, will be capable of giving shelter to thirty or thirty-five vessels. The average depth of water will be from 20 to 40 feet. Our survey of the country and the subsequent trial sections of the engineers, extended from the coast to within sight of the Euphrates, taking in the towns of Antioch and Aleppo. Beyond the latter, all engineering difficulties cease, the country presenting a hard dry level surface (called in Arabic "Ka Jalide,"—flat and hard), most admirably adapted for a railway. And even between the Mediterranean and Aleppo the difficulties are such as would be considered small in this country. There will not be a single tunnel, and only two cuttings of any consequence. Two chain bridges over the Orontes will be necessary; but neither do these present any obstacle to the engineering science of the present day. The estimated expense of the whole line is £6,000,000.

It is impossible to over-estimate the political and commercial advantages which England would derive from the opening up of this most fertile country. History proves what a powerful influence has at all times belonged to the possession of the Valley of the Euphrates; and to science, to the geologist, the naturalist, the ethnologist and the archæologist, fresh and most interesting fields of inquiry would be opened by this line of communication with India. The difficulties of dealing with the Arabs have been much exaggerated. They are a singular people, combining the extremes of good and evil in their character. But with good faith on our part, judicious management, and a little foresight, there would be little to apprehend from them. The chief difficulties in dealing satisfactorily with the Arabs would arise from their ignorance, the hostile state of their tribes, and their blood feuds. But I know

from experience, that by moderation, tact, and truthfulness on our part, these may be overcome.

With regard to a telegraphic communication with India by this route, two lines have been proposed; the one along the Red Sea to Kurrachee, the other along the Valley of the Euphrates to the same part. Both would seem to be most desirable, if not necessary. To effect this a submarine cable should be laid down from Kurrachee to Ras-el-Had, or some other place near the entrance of the Persian Gulf. Thence the proposed respective companies could carry their lines to England, the one by way of Suez, and the other by the Persian Gulf. The Red Sea line, by following Arabia, at a short distance from the coast, would encounter depths varying from 20 to 100 fathoms nearly the whole way to Suez; coral rocks are only occasionally met with, and we should have the advantage of knowing where an accident might occur, and prepare the means in consequence of recovering and repairing the broken pieces of the cable: so that the completion of the line from Ras-el-Had to Suez does not seem to offer any practical difficulty. For the other line, there is a choice of two routes across Asia Minor from Constantinople, as far as Aleppo by one line, and as far as Dyarbekir by the other: no difficulties whatever exist. But beyond these places the Arabs are to be taken into account, but this is only for a limited distance. The line of the railway would ultimately be the preferable one, but for immediate operation the other might be somewhat quicker. The work might therefore be commenced simultaneously at each extremity. A submarine cable could be laid down from Ras-el-Had to Kurnah, and from the latter place to Bagdad, along the bed of the Tigris; and again between Constantinople and Dyarbekir, beginning at several places at once in each part of these lines. The middle part only would be wanting from Dyarbekir to Bagdad, and this might be completed by a line of Tartars; and thus we should very soon be in possession of two lines of electric wires to India.

The line of communication with India proposed by the French, would traverse Asia Minor more to the northward than that which I have advocated, so as to come into this line towards the head of the Euphrates. Unlimited funds might, doubtless, accomplish this, but my local knowledge gives me the firm belief that the Taurus can only be passed, without an absolutely ruinous expense, in the direction of Adana and the Orontes. The French have long seen the importance of the Valley of the Euphrates. They seem to know and feel, as the great Oriental scholar Dr. Sprenger has said, "that its possessor holds the key of the Eastern world." It is, in fact, a country far richer and more valuable than Egypt, and England, therefore, has now at her feet the opportunity of acquiring the means of greatly increasing her commerce, of consolidating Turkey, and of securing our Indian territory both from internal and external dangers; and the proposed railway would be the means of repaying to the East, with tenfold interest, that knowledge and those blessings which came to us originally from thence.

On Australian Crania. *By* Professor J. H. Corbett.

Professor J. H. Corbett exhibited crania, which had been selected by the late Dr. John A. Corbett, R.N., in the neighbourhood of Port Essington, North Australia, as affording characteristic examples of the heads of the Aborigines of that country.

The texture of the cranial and facial bones is strong and compact. The superior maxillary bones exhibit the prognathous tendency in a marked degree. The frontal region may be described as receding, but by no means deficient in height; the temporal regions are much flattened; the perpendicular measurement of head from the margin of the foramen magnum to the vertex is equal with European heads; the antero-posterior measurement of the cranium is somewhat from half to three quarters of an inch greater than that presented by many European skulls. The internal capacity of these crania was found to be exactly the same as that of several European crania of average size, which had been examined; the method adopted for this purpose being that of sealing up the several apertures, and then filling the head with fine sand introduced through the foramen magnum. This mode of examination tends to show, that the Australian crania are capable of lodging an amount of cerebral matter just equal to that of many European skulls, although the form of the brain must be

necessarily modified and moulded in adaptation with the cranial conformation. In these heads, the cerebellar compartment is not in the least degree larger than in European crania.

On the Character, Extent, and Ethnological Value of the Indo-European Element in the Language of Finland. By RICHARD CULL, *F.S.A.*

The author stated that his would differ from the ordinary form in which papers and communications are presented to the Section. The shortness of time allowed for each paper, the difficulty and extent of the inquiry, and the inability of philological papers to arrest the continuous attention of a mixed audience, induced him to describe simply the method of his investigation, to read portions of two chapters of his forthcoming work on the Finn language, to state some consequences which result from the discovery of the great relationship of the Finn language, and to offer a few remarks in conclusion.

The existence of Greek and Latin words in the Finn language was pointed out by Juslenius in 1712; and Palmroth had previously, in 1685, called attention to certain Greek words in the language. Professor Key drew attention to the subject in 1846, in a short notice of the 'Grammatica Lapponica' by Fiellström, Stockholm, 1738, and the 'Grammatica Finnica' by Vhael, Abo, 1733, in a paper entitled "The Lapp and Finn tongues not unconnected with the Indo-European Family. By T. Hewitt Key, A.M.*" Mr. Wedgwood has since drawn attention to the subject by pointing out a number of words which he deems to have miscellaneous affinities with many of the Indo-European languages†. Their views, however, are not generally accepted.

The base or root of most Finn words is bisyllabic. The syllables commonly begin with a consonant and end with a vowel: some syllables, however, end with a consonant, of which the most common are *k, l, m, n, s* and *t*, but *n, s* and *t* are the only consonants found at the end of words. A few syllables occur with two final consonants, and some with two initial consonants; but these are in recently imported words of Swedish origin and chiefly Biblical proper names.

The Swedish words which have been incorporated in the Finn language have either naturally, or by artificial means, the peculiarities which characterize Finn words, as in the following examples :—

Swedish.	Finn.	English.
Venus	Wenus‡	Venus.
Kassa	Kassa	Cash.
Kaffe	Kahwi	Coffee.
S°pa	Saipo	Soap.
Stol	Tuoli	Chair.
Fläsk	Läsku	Pork.
Gaffel	Kahweli	Fork.
Fjeder	Wietari	Pen.
Glas	Lasi	Glass.
Stråt	Rata	Street.
Bössa	Pyssa	Musket.
Dosa	Tuusa	Box.
Doctor	Tohtori	Doctor.
Gips	Kipsi	Gypsum.
Krydda	Ryyti	Spice.
Skräddare	Räätali	Tailor.
Flagga	Laku	Flag.
Muff	Muhwi	Muff.
Skruf	Ruuwi	Screw.

* Proceedings of the Philological Society for 1846. † Ibid. for 1856–57.

‡ In the Finn orthography *f* is written by *w*; *b, d* and *g* hard are unknown to the Finn, except under peculiar conditions. The general principles of Swedish orthography obtain in the Finn language.

Swedish.	Finn.	English.
Krämare	Räämali	Shopkeeper.
Skrifvare	Riiwali	Clerk.
Qvast	Wasta	Broom.
Garfvare	Karwali	Currier.
Snus	Nuusku	Snuff.
Staff	Tawi	Staff.
Fogde	Wouti	Steward.
Jägare	Jääkeri	Huntsman.
Aktor	Ahtori	Agent.

The above selected examples are sufficient to indicate the nature of the modifications which Swedish words have suffered on their incorporation in the Finn language. The author has collected and classified every Swedish word in the Finn language under three general heads, viz. (α) unchanged, (β) changed, and (γ) greatly changed in form. The several means adopted to bring Swedish words to the Finn form were briefly described.

The existence of such words as—

Indo-European.	Finn.	English.
Sutor	Suutari	Cobbler.
Femina	Waimo	Woman.
Arca	Arkku	Box.
ἔρημος	Erama	Desert.
ἵππος	Hepo	Horse.

and others equally like, suggested a careful study of Finn words in relation to those of the Indo-European languages. The result of this comparison was the discovery of a large number of Indo-European roots which appear to have suffered modifications precisely similar to those which the Swedish words have undergone. The following specimens are sufficient to indicate the nature of this discovery:—

Indo-European.	Finn.	English.
θρίαμβος Triumphus	Riemu	Triumph.
θύελλα	Tuuli	Tempest.
μάχαιρα	Miekka	Sword.
ἐγχεία	Keiha	Spear.
Clypeus	Kilpi	Shield.
οὖθαρ	Utar	Udder.
πρυτανὶς	Rutinas	Prince.
σπειρὶ *περὶ*	Püri	Circle.
σωρὸς (a heap)	Suuri	(Great, large).
τρώγημα	Ruoka	Food.
φλὸξ	Liekki	Flame.
φθεὶρ	Täi	Louse.
φὼρ	Waras	Thief.
χὴν Anser	Hanhi	Goose.
αὐλὸς	Huilu	Pipe, Flute.
Cæcus	Sokia	Blind.
Mahi (Sanskrit)	Maa	The Earth.
γράμματα	Raamattu	Writing.
εἰκαῖος	Heikko	Weak.
κῦδος	Kütos	Renown.
πλοῖον (a ship) *λαῖφος* (a sail)	Laiwa	Ship.
ὀρφανὸς	Orwo	Orphan.
κατὰ	Kautta	According, by, through.
ἀμφὶ	Ympäri	What is about.

The long lists of words from which the above selected vocabulary is taken are too numerous and regular to be examples of mere accidental coincidence. They are words, too, that form the basis or groundwork of speech, and not such words as are commonly imported from one language to another by the fortune of war, or by the peaceful intercourse of commerce. Hence it is impossible to escape the conclusion, that the Indo-European element of the Finn language is an essential fundamental element pervading the Finn language; and being so, the Finn language must be grouped as a member of the Indo-European family of languages. This philological result is of ethnological value; for as we are justified in assuming that peoples speaking languages of a common origin have themselves a common origin, we are bound to assume the Finns to be of the same origin as the rest of the Indo-European nations. And all the Finnic tongues, as the Hungarian, the Lapponic, the Esthonian, and those of the isolated tribes in the Russian Empire, as the Karelian, the Cheremissian, the Sirjanian, &c., must with the peoples speaking them be admitted into the Indo-European family of tongues and peoples.

There is no time even to state the consequences of this admission, but the close connexion of the Turanian and Indo-European families of languages by means of the Finnic dialects is too important not to be named.

On China, in more immediate reference to pending Operations in that Quarter. By Sir John F. Davis, *Bart., K.C.B., F.R.S.*

The paper, after some general remarks on the interest of the subject at the present moment, enters into a running but graphic description of the coast of Canton river, Chusan, Shanghai, &c., showing the facilities which in many places they afford for defence, and for annoying the hostile fleet, but at the same time the facility with which any such annoyance on the part of the Chinese could be overcome. With respect to Canton, Sir John says,—"It seems at once good policy as regards the Cantonese, and mere justice and humanity towards the better-disposed populations towards the north-east, that, if a lesson is to be administered, it should be administered in the right quarter. Topical evils require topical remedies, and if we were once more to leave Canton to itself (as we have done before), the question would again be asked, which was so often asked then, 'Why did you not address yourselves to those who had offended you, and were prepared to resist you, instead of attacking us?' At Canton, besides, there is nothing at present to lose, for all trade has left it, and all the foreign quarter is in ruins. The complete capture and occupation of the city, and the heights behind, by our troops, with Hong-Kong and its harbour, its barracks and its hospitals, for the base of operations, would at once dispel the delusions of the Cantonese, and supply us with a material guarantee and pledge, as long as it was retained, for all that we have to require from the Pekin Government. These two points seem to comprise within themselves the objects of the expedition, that is to say, satisfaction for the past and security for the future; and as the surest way to the second, the first seems indispensable, viz. the capture and occupation of the provincial city."

On the Physical Characteristics of the Ancient Irish. By John O'Donovan, *LL.D.*

The author argued at full length to prove that the ancient Irish were a large race of men, warlike and vigorous, from the poet Claudian and the Christian father St. Jerome, the latter of whom describes a Scot from the neighbourhood of Britain, as "*canem grandem et corpulentum, et qui calcibus magis possit sævire quam dentibus.*"

Passing over many fabulous accounts of the gigantic size of the ancient Irish, he dwelt with particular emphasis upon the description of the stature and personal appearance of the Irish people given by Giraldus Cambrensis in 1183, before they had received any admixture of Saxon or Anglo-Norman blood. In his 'Topographia Hiberniæ,' Dist. i. c. 19, Giraldus says that all the animals in Ireland were smaller than those he had seen in other countries, except man, "who alone retained his majesty of stature;" and in Dist. iii. c. x., where he says that (although the Irish were no adepts in the science of nursing) their children nevertheless grew up by

nature to be of beautiful, tall, and strong persons of well-formed and well-coloured faces:—"Tanquam itaque Natura probans quid per se valeat fingere, non cessat et figurare quousque in robur perfectum, pulcherrimis et proceris corporibus, et coloratissimis vultibus, homines istos provehat et producat."

On the Intellectual Characteristics of the Ancient Irish. *By* JOHN O'DONOVAN, *LL.D.*

The author laid particular stress upon a passage in Bede's 'Ecclesiastical History,' lib. iii. c. 7, to prove their love of learning and their wish to impart it to the Saxons, while their neighbours the Cymri or Welsh people were unwilling to communicate any literary or religious instruction to the Saxons. He next glanced over the history of various Irishmen who distinguished themselves on the Continent by their learning, as Columbanus of Bobbio, St. Fursey of Peronne, St. Fridolin, St. Gall, Virgilius, Solivăgus the Geometrician; Alcuin, Dungal, Joannes Scotus Erigĕna; whose learning and scepticism were most remarkable for the age in which he flourished; Marianus Scotus, &c.

On the Surnames of the Irish People, their Meanings, and the various changes which they have undergone since the English Invasion of Ireland. *By* JOHN O'DONOVAN, *LL.D.*

On this subject, to which he had devoted much time and study, the author intended to publish a dictionary of Irish surnames, in which he would give the history, location, and census of all the families of Irish and Anglo-Irish descent now in Ireland, with references to all the ancient Irish and Anglo-Irish documents and records, in which the origins and particular histories of these families are to be found, and to the churches in which they have been interred.

On the Probable Migrations and Variations of the Earlier Families of the Human Race. *By* Rear-Admiral FITZROY, *F.R.S.*

In one of the first places which the author visited on the opposite side of the world, he found no fewer than twenty-eight varieties of man. They were all distinct, known by different names, and classified by no less an authority than Humboldt. It was the city of Lima, in Peru; where one now may watch the colour, features, and form of almost every variety in the world. He was greatly struck by this aggregation of colours and appearances. We all know that in Lima 400 years since, there were only three distinct varieties; 500 years ago there was but one race (apparently) in Lima, the aboriginal Peruvian; next the Spaniards (or Whites) came, and with them Negroes from Africa: from which three sources have sprung in the short space of 300 years all those varieties which are now so distinctly marked. In some parts of India, also, there are numerous races, and in the Mauritius there are likewise many varieties.

It is desirable to keep in mind three particular epochs in the world's history, namely,—

1st. The commencement of this century.

2ndly. About 3000 years ago; and

3rdly. The earliest dispersion of the human race.

First, as to the world's population at the beginning of this century. At that time there were in existence in Van Diemen's Land, a few remnants of an aboriginal race, which have since vanished. There were in Africa the genuine black man, the brown Moor or Berber; the red man, or Caffre; the Hottentot, and the Bushman. The latter are frequently regarded as degenerated varieties, but those who have seen the interior of that country know that they cannot be so classed. In America, from Cape Horn to the Arctic Circle, we then found the same race of men—the same colour and hair. Having (twenty-five years ago) brought home four natives of Tierra del Fuego, who remained with him for three years, the author was naturally much struck on seeing an Esquimaux brought to England by Captain Ommaney, precisely like the Fuegians in all respects; and as we know the habits of those who wander in canoes along the South American and the North American coasts

are similar, this would seem to show that the original stock was the same. From this and other facts, the author thinks that all the tribes of America are of one aboriginal race, except those of Eastern Patagonia.

In Asia the inhabitants of the Northern and Eastern parts are generally of a yellower hue, but do not differ much in feature from the Americans. In the west of America, the natives look to the West as the place from which they came, and bury their dead towards the West (placing them "towards the spirits of their ancestors," as they say); while the natives of the east coast of Patagonia point to the eastward as the quarter whence they came, and they bury their dead on the highest hills to the eastward for a similar reason. It is remarkable that none of them derive their origin from their present localities in America. In Africa the natives point to the North as the place of their origin; and, briefly, all aboriginal tribes have been found by travellers and the learned to derive their origin more or less directly from the central regions of Asia.

It may be asked, How could they have migrated so far in those early days? Land travelling probably was not difficult, however slow, while the power of crossing the sea in early times is not perhaps sufficiently appreciated in general. The double canoe of the South Sea or Polynesian Islands is not commonly known, and is nearly extinct as it formerly existed.

It was one of the most sea-worthy vessels that could have been devised in those primitive times, and in such vessels families could have migrated not only along coasts, but across oceans; where no doubt they were liable to be driven far away from their intended destination by unexpected winds, and perhaps currents. Such casualties may have been the cause of early cannibalism.

Regarding the possible connexion of those who migrated from Asia (the Tartar and Malay race) with the tribes of the west coast of America, independently of intercourse by Behring's Strait, the author remarks that if Malays were driven into the winds which always blow westward—anti-trades or moonsoons—they *must* go towards the coast of America, which we know has happened within the last few centuries, and would account for their derivation of origin from Asia.

The habits and appearance of the Aborigines of Chiloe and Western Patagonia correspond with many of the New Zealander's peculiarities. The black races of Polynesia are a mixed breed, between the genuine Negro and the reddish-brown man, or Malay.

On one little island of the Indian Ocean (the Keeling or Cocos), an Englishman was found married to a mixed or half-breed Malay. Their children were of a rich bright red copper colour. Some children of Englishmen and native New Zealand women were not of that colour in the first generation, but were so in the second. Of this the author can bear ocular testimony. The result of the whole inquiry is thus expressed:—"To reduce races to their original or primitive number, we can only reach to the white and the black by tracing back the intermixtures." The author concludes by referring to some passages of the Scriptures which bear on this subject.

On some Skulls discovered in an ancient Sepulchral Mound near Mount Wilson in King's County, Ireland. By John Grattan.

On the Progress already made in the Transcription and Translation of the Ancient Laws of Ireland, called the Brehon Laws. By the Rev. Professor Graves.

The author referred to the array of quarto MS. volumes on the table before him, as evidence of the amount of work that had been already accomplished. The first thing done, after ascertaining all the MSS. of those laws that were to be found in the libraries of Trinity College, the Royal Irish Academy, the British Museum, and the Bodleian Library, was to entrust the transcription to Dr. O'Donovan and Mr. Curry. This was commenced in 1853; and at the present time about six thousand quarto pages of manuscript had been transcribed, and about two thousand pages had been translated. The transcript had been executed in anastatic ink, which enabled them to make several copies,—one great advantage of which was that they had been

able readily to compile a vast glossary of the words used in the laws, with all the quotations to illustrate their meaning, arranged alphabetically. He had to mention, as an interesting fact, that Mr. Curry had been enabled, by this glossary, to investigate some of the legal terms in the ancient Welsh laws, which the Welsh translators had been unable fully to explain. The language of these manuscripts was very ancient, and the writing was in many places scarcely legible: hence it was impossible to estimate the amount of labour and of eyesight expended on them. This great work, however, was worth all the labour devoted to it. It was a most important contribution to our history, for nothing better explained the history and manners of a people than their laws and institutions. They throw a light even upon the history of other countries. The glossary which they had formed would be of the utmost value for the knowledge of the Celtic languages; and he had no doubt that the Brehon Laws would present to us a picture of the civilization of this country as it existed from twelve to fifteen hundred years ago. What length of time would be requisite, he might be asked, until this work would be completed? He had already told them what had been done in the last four years, and if it took as much more it would be worth the expense. He was happy to inform them that there was no fear that the work would be left unfinished. At the close of the late session of Parliament the Government had provided ample means for completing and publishing it.

The Rev. Professor GRAVES made a communication, the object of which was to identify the river Dur, mentioned by Ptolemy in his description of Ireland, with the Kenmare river. The principal argument by which Dr. Graves endeavoured to establish this conclusion, rests on the fact that at the mouth of the Kenmare river is an island retaining to this day the name of Dursey. The obvious and certain derivation of this name is Durs-ey, *i. e.* the "Island of Dur," "Dur" meaning *water*. Dr. Graves noticed that the termination "ey," meaning *island*, entered into the names of Dalkey, Ireland's Eye, and Lambay, on the Irish coast, not to mention Anglesey and other islands on the coast of Britain. The order in which Ptolemy enumerates the principal headlands, rivers, and maritime towns of Ireland also shows that the river which he calls the Dur is on our south-west coast. Ware and O'Connor have expressed the opinion that the Dur of Ptolemy was Dingle Bay, or Castlemaine Bay, but they have stated no grounds for their belief. Dr. Graves concluded by observing that the Irish topographical names appearing in Ptolemy's list deserve a more complete discussion than they have yet received.

On the Influence of the Gulf-stream on the Climate of Ireland. By Professor HENNESSY, *F.R.S., M.R.I.A.*

By referring to a large map of the British Isles*, the isothermal lines, or lines indicating the distribution of equal temperature, were shown to run not even approximately in the direction of the parallels of latitude, as might be expected, but in curves almost concentric, and following very nearly the windings of the coast. These relations to the coast line illustrated a fact first pointed out by Dr. Lloyd, President of the Association, which was deduced from a series of both day and night observations, namely, that the mean temperature of the sea off the west coast of Ireland is four degrees higher than the main temperature of the land. All these facts are easily explained by the phenomenon of the Gulf-stream, or warm current of water, which, as is well known to navigators, flows from the Gulf of Mexico in the direction of those islands and the north-west coast of Europe. That current of water, heated in the warm regions where it commences, exercises its influence very sensibly on the atmosphere, raising its temperature, and charging it with vapours, which are known to give out a certain amount of heat during their subsequent precipitation. From Dr. Wilde's historical 'Report on the Diseases and Cosmical Phenomena of Ireland,' presented with the Census returns, extreme depressions of temperature appear to have taken place in remote ages in that country; and such changes might have been

* A copy of this map has been published in the 'Atlantis' for July 1858, and in the 'Proceedings of the Royal Society,' Part 32.

caused by the temporary deflection of the Gulf-stream, arising from some perturbation in the Atlantic, thus leaving the island for the moment in the same position as continental regions under the same parallel of latitude.

On the Round Towers of Ireland. *By* Gordon M. Hills.

The author exhibited drawings, forty-four in number, illustrating forty of the round towers, being the first portion of a survey still in progress, which is intended to include drawings of every round tower in existence, with the architectural features of each shown at large, and the dimensions taken either by actual measurement or by the sextant and artificial horizon. The survey extends to the churches and buildings adjacent to, or in connexion with the round towers; and in addition, to the sites and buildings where there is authority for believing that round towers have existed.

An abstract of the particulars given of the first portion of the survey is as follows:—

1st. Towers retaining the conical cap complete, or nearly so.

	High to top. feet.	in.	Diameter at base. feet.	in.
1. Kilmacduagh, Co. Galway	108	4	18	6
2. Ardmore, Co. Waterford	95	10	16	4
3. Clondalkin, Co. Dublin	90	5	13	4 (at door)
4. Cashel, Co. Tipperary	89	0	16	8
5. Antrim, Co. Antrim	87	0	16	0
6. Swords, Co. Dublin	85	9	16	10
7. Devenish, Co. Fermanagh	81	6	15	6

No. 1 has lost about 3 feet of the point of the cone, 3 and 4 have lost about 18 inches each.

2nd. Those towers which are perfect to the base of the cone, or retain only a small portion of it:—

	High to base of cone. feet.	in.	Diameter at base. feet.	in.
1. Fertagh, Co. Kilkenny	100	0	15	8
2. Kilkenny	95	5	14	10
3. Glendalough, Co. Wicklow (the Great Tower)	90	0	16	0
4. Lusk, Co. Dublin	88	0	17	0
5. Timahoe, Queen's Co.	80	5	18	4
6. Rattoo, Kerry	78	4	15	1
7. Scattery, Co. Clare	76	9	16	7
8. Clonmacnois, King's Co. (the Small Tower)	45	3	11	7

3rd. The following, which have had battlemented additions made to the height of the shaft in modern times:—

	High to top.		Diameter at base.	
1. Cloyne, Co. Cork (a stump)	101	5	17	1
2. Kildare	96	0	17	10
3. Kilree, Co. Kilkenny	85	8	15	10

4th. Those which are imperfect in various degrees:—

	High.		Diameter.	
1. Aghadoe, Co. Kerry	16	0	15	6
2. Ardpatrick, Co. Limerick (a fragment)	...		16	9
3. Armoy, Co. Antrim (a stump)	33	0	15	0
4. Aghavuller, Co. Kilkenny (a stump)	29	0	16	0
5. Castledermot, Co. Kildare (top modern)	65	6	15	3
6. Clones, Co. Monaghan (to top of window under cornice)	70	10	16	4
7. Clonmacnois, King's Co., O'Ruark's Tower (the upper part not original)	56	9	18	6

	High. feet.	High. in.	Diameter. feet.	Diameter. in.
8. Drumbo, Co. Down (a stump)	33	0	16	5
9. Drumclewe, Co. Clare (a fragment)	50	0	16	0
10. Dysart, Limerick Co. (an imperfect shaft)	64	0	17	4
11. Dysart O. Dea, Co. Clare (a fragment)	50	0	19	5
12. Inniscaltra, Galway (imperfect shaft)	70	5	15	0
13. Kilcullen, Co. Kildare (a stump)	30	9	15	0
14. Kilmallock, Co. Limerick (much altered from its original state)	57	0	16	10
15. Kumeagh, Co. Cork (imperfect shaft with hexagonal base inscribed in a circle)	67	3	21	0
16. Monasterboice, Co. Louth (imperfect shaft)	76	6	15	1
17. Oughterard, Co. Kildare (a stump)	40	0	15	0
18. Roscorn, Galway (a stump)	32	0	15	9
19. Roscrea, Tipperary (an imperfect shaft)	69	0	14	9
20. Tullatrerin, Co. Kilkenny (the top not original)	73	3	16	0

Killashee, Co. Kildare, has a square base; St. Kevin's Tower, Glendalough, Co. Wicklow, stands on the vaulted roof of St. Kevin's Church at the west end. It is perfect, and measures 46 feet high from the ground to the apex.

On the relation between the newly-discovered Accadian Language and the Indo-European, Semitic, and Egyptian Languages; with remarks on the original values of certain Semitic Letters, and on the state of the Greek Alphabet at different periods. By the Rev. E. Hincks, *LL.D.*

The facts from which the author proposed to reason relate to the language of the Assyrians, the mode of writing of the Assyrians, and the language of the people who invented this mode of writing, or, as they have been called, the Accadians. The Assyrian language is a member of the family which has been generally called Semitic. This term may be retained, as no preferable term presents itself; but is objectionable, as we have no reason to suppose that the divisions of mankind with respect to language and with respect to descent were coincident. All the Semitic languages that were known before the discovery of the Assyrian agree with one another in some important particulars in which they differ from the Assyrian. For example, they have H in the separate pronouns and affixes of the third person, and in the preformative of causative verbs; while the Assyrian has S. They may be classed together as the Syro-Arabian sub-family of the Semitic family of languages; the Assyrio-Babylonian being its other sub-family.

The grand distinctive feature of the Semitic languages is that in them the roots are *consonantal*. Most commonly, they consist of three consonants, or what are considered as such; but in no instance does a *vowel* form part of the root. The vowels are used to determine the grammatical forms, which they sometimes do alone, but oftener with the assistance of consonants, prefixed or suffixed to those of the root or inserted among them. In all other languages, on the contrary, the roots are *syllabic*; though in many languages the vowels are liable to be changed in certain grammatical forms, and consonants may be inserted within the roots. Besides the ordinary consonants, the semi-vowels W and Y, and certain breathings, there are combinations of consonantal sounds, which are treated in Semitic grammar as simple consonants.

Now this distinctive feature of Semitic language, that its roots are consonantal, connects itself naturally with a distinctive feature of Semitic writing. It is consonantal. Its characters represent those consonants, or what were considered as such, which are capable of being elements of roots. It has, properly speaking, no vowels. In Hebrew, as it is now printed, there are points attached to the letters, which indicate the vowels with which these letters are to be sounded; but it is generally admitted that these points were no part of the original text. There are also some letters, which in certain cases supply the place of vowels when the points are not written.

The most common of these are *Vaw* and *Yod*, which express the vowels U and I, as well as the semi-vowels W and Y. There can scarcely be a doubt, however, that in some cases where these letters are now read as vowels, they were originally read as semivowels; the *ôth* of the feminine plural was originally *áwath*; the *i* of the affix "my" was originally *ya*. In other cases, these vowel letters were inserted by copyists at a comparatively recent period; according to Dr. Wall, in the second century after Christ. In the oldest Phœnician inscription extant, that on the sarcophagus of Asmunezer, there are no vowel letters. The *Yod* of the plural number is never written in either the absolute or the constant form; there is no *Vaw* at the end of the third person plural, and no letter after *Zayin* in the demonstrative pronoun.

All the Semitic languages with which we were acquainted previously to the deciphering of the Assyrio-Babylonian inscriptions were originally written from right to left, and with consonants only; and no languages other than Semitic ones were thus written, except under Semitic influence. It was therefore a natural supposition that the cuneiform writing of Babylon, where a Semitic language was believed to have been spoken, would be written with characters which represented the Semitic consonants. Two circumstances might have suggested doubts as to this being the case; the writing was directed from left to right, and the characters were far more numerous than in the Semitic alphabet; but notwithstanding these objections, all who undertook the decipherment of the inscriptions before 1847, with the single exception of Grotefend, referred the characters to the Semitic alphabet. The explanation which they gave of the large number of the characters was that each letter was represented by several equivalent characters; and that some characters represented combinations of letters, *Aleph*, *Vaw*, and *Yod* being accounted vowels. Grotefend denied the equivalence of any two characters, and supposed that characters might represent consonants, combinations of consonants, vowels or syllables. Grotefend identified the Babylonian groups which represented the names of Darius, Hystaspes, and Xerxes; and his analysis of these names might pass if no other words were to be considered; and so indeed might that of the other decipherers; but both these systems failed when the values of the characters used in these words were transferred to other words in which the characters occurred. In the latter end of 1847, it occurred to the author of this paper that the characters must represent definite syllables, no character representing a detached consonant, and no vowel being left unexpressed. He considered that the Assyrians did not analyse their words beyond syllables; they did not recognize consonants or vowels as constituents of syllables; their characters represented simple syllables or combinations of syllables; not Semitic letters or combinations of them, as the French decipherers and Sir H. Rawlinson supposed, nor European letters and combinations of them, as Grotefend thought. These three modes of analysing the names of Darius and Hystaspes were represented in fig. 1 of a lithographed plate, which was distributed in the Section (Plate III.). It was observed that, so far as respected these two names, the difference between these different modes might appear unimportant; but the problem to be solved was to analyse these names in such a manner as that the values of the characters deduced from these and other like names, when substituted in Assyrian nouns and verbs, would enable us to exhibit them in Semitic forms. The first two modes of analysis failed to do this, but the third effected it. In a lithographed plate, which was exhibited at the Edinburgh Meeting of the British Association in 1850, and which was published in the Report for that year, there were a number of groups of cuneatic characters, which were read syllabically as Semitic words. Though there were errors in most of these words, which have since been corrected by the author himself or by others, they were such close approximations to the true reading of the words, that they could scarcely fail to carry conviction to those who were studying the inscriptions. The syllabic system of deciphering, which had previously been maintained by the author alone, is now universally adopted.

This, then, being a settled point, it comes to be inquired, how came the Assyrians to write on a totally different system from what all other Semitic people used? The answer to this question given by the author in 1850 was, that the Assyrians learned their system of writing from a non-Semitic people. He then thought that this other people had partially adopted the Egyptian system of writing; but he was now satisfied that they had invented it independently of the Egyptians. What suggested to

him that the inventors of cuneatic writing were acquainted with hieroglyphic writing, was that ideographic characters were mixed with phonetic ones in both the systems. This alone, however, would not prove that this was the case; for ideographic characters are mixed with phonetic ones in almost all systems. The Arabic and Roman numerals, the signs for degrees, minutes and seconds, and for the different denominations of money and the like, are ideographic. These have not been borrowed from either the Assyrian or the Egyptian system; why then should it be thought that one of these was borrowed from the other? Unless the ideographs were introduced among the phonographs in a strikingly similar manner in the two systems, it would by no means follow that one system was taken from the other. The author, however, denied that they were introduced in a similar manner. The Egyptians sometimes wrote the name of an object phonetically, and added the figure or symbol of the object; but the Assyrians never did so. They wrote down the word or they wrote down the sign; but they never wrote down both, one after the other. At other times, the Egyptians wrote the name of an object phonetically, and wrote after it the ideograph, not of the object, but of the species or genus to which it belonged. The Assyrians did something like this, but not this. They prefixed the ideographic sign of the species to the name of the individual, or that of the genus to the name of the species. They prefixed what the Egyptians postfixed. Surely, if they had learned the use of determinative signs from the Egyptians, they would have used them as the Egyptians did. Again, compound ideographs are used in Egyptian writing; but though there appear to be instances of the use of them in Assyrian writing, these are capable of a different explanation, which is probably the true one. In fig. 2, we have a combination of two characters, which signifies "a son;" the characters signifying severally "child" and "male." Sir Henry Rawlinson has, however, suggested that these characters, which have the phonetic values *tur* and *us*, represent words of the Accadian language to which the cuneatic writing was first applied. These Accadian words, when alone, are interchanged with the equivalent Assyrian words which are beneath them in the figure, being written when those Assyrian words should be read; and in like manner the compound Accadian word *Tur-us*, "a male child," is written when the equivalent Assyrian word *pal* should be read. This Accadian compound is interchanged with a simple Accadian word for "son," which was probably pronounced *hwah*; both Accadian forms being equally read as *pal*. A great deal of the supposed ideographic writing of the Assyrians is thus, in fact, a writing down of Accadian words, when the equivalent Assyrian words are to be read; a mode of proceeding which was certainly not learned from the Egyptians, who practised nothing at all like it. Strange as this mode of proceeding must appear, and as it certainly is, it has some resemblance to what occurs in English. Abbreviations are frequently used, which represent Latin words, and which are nevertheless read by English words. Thus "£" represents "*libræ*," but is read "pounds;" "e. g." represents "*exempli gratia*," but is read "for example." It thus appears that so far as respects their use of ideographs, there is very little resemblance between the Assyrian and Egyptian systems of writing; certainly not enough to require us to attribute to them a common origin. Let us now look to the forms and values of the characters. In both systems we have representations of "the mouth" and of "water;" but they are as unlike as it would be possible to make them (see fig. 3). The Egyptians represented the mouth as seen in front, the Assyrians as seen from the side; the wedges represent the lips, the line of the face, and the mouth itself. The Assyrians represented water by drops of rain; the Egyptians by the waved surface of standing water. Surely there would not have been such differences if one system had been taken from the other. Again, the Egyptian characters for the most part represented incomplete syllables, requiring vowels to be supplied which were not expressed; whereas the Assyrian characters all represented complete or definite syllables, in which no vowels had to be supplied. The Egyptian syllabic characters differed in another respect from the Assyrian ones. They admitted complementary letters, as they are called; sometimes before them, sometimes after them, and sometimes both before and after them; while the Assyrian characters had no complements. To show the nature of the complementary characters of the Egyptians, and at the same time the uncertainty of their writing, owing to the absence of vowels, two syllabic characters are given in figures 4 and 5, with the variations of which the

writing of them admits, and with the equivalent Hebrew and Roman characters. The first character in fig. 4 represents *Aleph, Mem*; and by the aid of the Leaf, *Aleph*, and the Owl, *Mem*, we have four modes of writing the syllable equivalent to the simple syllabic character. None, however, of the five modes of writing distinguishes the vowel. All these modes are equivalent to a pair of Hebrew letters; but they represent three different combinations of Roman letters; to each of which a distinct Assyrian character corresponds. In fig. 5 there is only one mode of completing the syllable used. Two Egyptian ways of expressing *Mem, Nun* were in use; and each might represent three syllables, two of which had Assyrian characters to represent them, while all three might be represented by combinations of two Assyrian characters, having the respective values of MA.AN, MI.IN and MU.UN. It appears, then, that the values of Assyrian and Egyptian characters are not even of the same kind. They could not be the same unless the value were a vowel; and in point of fact they never are the same.

Dismissing then the idea that the Assyrian mode of writing was in any respect derived from the Egyptians, we have to seek its origin in the lower part of the valley of the Euphrates, where the clayey nature of the soil would account for the plastic character of the writing. The name of Accad occurs in Gen. x. 10, as that of one of the earliest cities in this district, and it is also found in the Assyrian inscriptions, apparently applied to the whole district. It has therefore been chosen with great propriety by Sir H. Rawlinson to represent the people who invented the Assyrian mode of writing. The language of this people may be called Accadian; and there are in existence ample means of attaining to the knowledge of its structure and its vocabulary. The sources of information respecting it are of three sorts. The bilingual tablets in the British Museum were written in the seventh century B.C. Some of these contain Accadian sentences and equivalent Assyrian sentences, either in parallel columns, or one beneath the other. In others, sentences in the two languages are analysed, so as to give the precise meaning of every element in the long Accadian words that we meet. In all the Assyrian inscriptions Accadian words are occasionally introduced; and when different copies of the inscriptions have been found, it often happens that one contains an Accadian word and another its Assyrian equivalent. The oldest Assyrian inscription of considerable length is that of Tiglath Pileser I., whose capital was sacked by the Accadians of Babylon 419 years before the first year of Sennacherib (702 B.C.). The inscription was therefore written a little before 1121 B.C. Inscriptions, the language of which is wholly Accadian, and which are anterior to the Assyrian ones, are said to be in existence; but copies of them have not yet been made public. A third source of information as to the glossary of the Accadian language goes back to the origin of this species of writing. The phonetic values of the characters used in the original writing of the Accadians were the names of the objects which the characters represented. We know what certain characters represented, and we know their phonetic values; and thus we come to know the Accadian names of certain objects at the time when this mode of writing was invented. We cannot assign the date of this invention; but we have a minor limit for it. In the inscription of Tiglath Pileser I., who began to reign about 1130 B.C., mention is made of a temple, which after standing 641 years, having become ruinous, had been taken down by the great-grandfather of this king, sixty years before his accession. Sixty is a round number, but is more likely to have been less than greater than the actual number; but the other number, which purports to be accurate, was doubtless taken from an authentic record. The temple would therefore have been built about 1830 B.C. Now, Tiglath Pileser found inscriptions written by its builder, who lived before the origin of the Assyrian monarchy; and we have thus the 19th century B.C. as the *latest* date at which the origin of Accadian writing can be fixed. Its actual date was in all probability several generations earlier. The bilingual tablets teach us that the Accadian language was in its structure as dissimilar as can well be conceived possible both to the Indo-European languages and to the Semitic ones. It had unmistakeable affinities with the language of the inscriptions found at Susa and in its neighbourhood, and with that of the Achæmenian inscriptions of the second kind. These latter had been supposed by Mr. Norris to be connected with the Ugrian languages; while others believed them to be represented by the Mongolian or Dravidian languages. The author, being unacquainted with

these languages, declined to express a positive opinion. As respected his arguments in this paper, it was of no consequence whether the Accadian language was represented by one or more living languages, or whether it had died away, like the Egyptian, leaving no representative on the tongues of men. He was inclined to think, however, that all the Turanian languages were descended, if not from the Accadian, from its parent the Japhetic, which is hereafter to be noticed; though from the long period which must have elapsed before these languages were reduced to writing, and from the barbarism and nomadic habits of most of the nations who spoke them, there can be little hope of the descent being traced in a satisfactory manner. It had been noticed, several years ago, that the Egyptian language was connected with the Semitic languages in respect to its glossary. The connexion was so manifest, that, notwithstanding the structural difference of the languages, Bunsen and others have classed the Egyptian among the Semitic languages. A glossarial resemblance between the Indo-European languages and either the Semitic or the Egyptian had also been remarked in some words. In the present paper, the author endeavours to establish this glossarial affinity between the three languages or families of languages that have been named, and the Accadian. The latter he regards as more closely connected with the Indo-European languages than with the other two. He supposes it to be a sister language to the primitive Indo-European language, from which all the existing languages of this stock are descended; and he supposes that the common parent of these two (and possibly of other Turanian languages), which he calls the Japhetic language, was a sister to the Semitic and Egyptian languages. The linguistic pedigree, according to the author's view, is found in fig. 6. It is inferred from a number of verbal pedigrees, such as that of the second numeral in fig. 7, in which it is to be observed that each word in the verbal pedigree is to be referred to that language, the name of which occupies a corresponding position in the linguistic pedigree. It is to be observed also that the Egyptian and Accadian words are directly obtained from inscriptions; but all the other words in the pedigrees are obtained by inference from what is otherwise known. The author's principle is, that when of the corresponding words in two sister languages, one is known, and a number of descendants of the other are also known, this other may be in general inferred with certainty. His mode of proceeding is illustrated by the numeral for "two." The Egyptian word is given in fig. 8. It occurs, Select Papyri, pl. 27. l. 11, where it follows the word עת, and implies that it should be doubled. Elsewhere it is found doubled. The identity of the word in both its forms is unquestionable from the peculiar monstrous bird which it signifies, by a representation of which it is followed. The first character in the hieroglyphic name might be read indifferently T, TH or D; the others represent W and Y, one of which at least must be read as a vowel. The Egyptians introduced vowel letters much earlier than the Phœnicians or Hebrews did; and these last probably learned the use of them from them. The Accadian word is used, like the Egyptian word, to denote duplication. The plural of the word signifying a city is written, for example, in three ways; and it should be observed that the Accadian plural was formed by doubling the singular. These are exhibited in fig. 9. The character is doubled; or the syllable *mi* is added; or a character is added, which has been called the plural sign. It is, however, composed of one of the forms for *mi* and *is*; and in the Syllabary, K. 110, it is directed to be pronounced *mis*. It might be argued, indeed, that the Accadian value of this word was rather "many" than "twice;" but the use of it in fig. 10 proves decisively that this was not the case. Some preliminary explanation is, however, required before the force of the argument drawn from this use of it can be seen. It has been stated that Accadian words were used in Assyrian inscriptions, in place of Assyrian words. When the words were verbs, it was customary to add to the Accadian verbal root the termination of the Assyrian verb. Thus the Accadian root signifying "to go" was *du*; and we have in the upper line of fig. 10 the equivalent forms (*du*) *ku* and *illiku*, both of which are found written interchangeably, but the latter of which was always read. The corresponding English verb would be "he has gone;" the final *u* not being a sign of the plural number, but of the preterperfect tense. In the following line we have three forms used interchangeably, which represent the corresponding frequentative verb *ittalaku*, "he has gone repeatedly." The Accadian

frequentative verb is formed by duplication; it is *du-du*. This gives (*du-du*) *ku*, analogous to (*du*) *ku* of the preceding line; and for this we have, in the great inscription of Tiglath Pileser I. (*du-mis*) *ku*. In this instance, it is impossible to assign any value to *mis* but "twice." The double Accadian form *mi, mis*, analogous to the Sanskrit *dvi, dvis*, and to the similar forms in Greek and Latin, is one argument out of many for the closer connexion of the Accadian with the Indo-European languages than with the Semitic and Egyptian languages. The form in *i* occurs in all the languages; the adverbial development in *is* is Japhetic, being common to both the Accadian and the Indo-European languages; but the adjectival declension is exclusively Indo-European.

Having obtained the Accadian form from the inscriptions, the author investigated the other forms in the verbal pedigree by inference from this form and the Semitic and Indo-European forms. There can be no question that the two last radicals of the primitive Semitic root for "two" were נִי. Before these some languages had שׁ, and others ת; the Arabs having their peculiar letter *Tha*. Again, there can be no question that the primitive Indo-European form had *v* or *w*, preceded by a dental, before *i*. Now *m* is interchangeable both with its fellow-nasal *n* and with its cognate labial *v* or *w*; whereas no direct interchange could exist between *n* and *v* or *w*. It necessarily follows that the primeval form had *m* before *i*; and as a double change in passing from the primeval to the primitive Semitic is not admissible, and as *tm* is an unpronounceable combination, these two forms must have been *thmi* and *thni*, the *th* being pronounced as in "thin." The Japhetic form must have been *thmi*, and the primitive Indo-European *thwi*; but in the last two words the *th* may have been sounded as in "thy;" and probably was so, as it is represented by *d* in the great majority of existing forms.

This may serve as a specimen of the manner in which verbal pedigrees have been formed. A list is given further on of Accadian words with the primitive Indo-European and Japhetic words, to which they and the known Indo-European words that correspond to them conduct us. It is necessary, however, to ascertain the original values of certain Semitic letters which occur in the Accadian words. It will be seen that the values which some of these letters had subsequently to the Babylonish captivity, were very different from what they had when the Accadian language was first committed to writing.

In the Achæmenian inscriptions *Samech* has the value S, and *Shin* SH. The Sibilant in the name of Darius and the former of those in that of Hystaspes, fig. 1, are represented by *Shin*, and in the first kind of Persepolitan writing by SH; the latter of the Sibilants in the name of Hystaspes is represented by *Samech*, and by S. This is in conformity with received opinion; but when we go back to the Assyrian inscriptions, we find a very different state of things. There, in the Assyrian representations of foreign proper names, the Hebrew *Shin* is represented by *Samech*; although in the roots which were common to the two languages *Samech* corresponds to *Samech*, and *Shin* to *Shin*, no matter where the diacritical point of the Masoretes be placed. This is invariably the case where the *Shin* precedes a vowel or an ordinary consonant, or terminates a word. Where, however, it precedes *Kaph* or *Qoph*, *Shin* and *Samech* seem to be used indiscriminately in Assyrian. To establish these facts, from which he inferred that *Shin* was always pronounced by the Assyrians as S, and that they used SK (which they represented by *Samech*) for the Hebrew SH, the author exhibited the following transcriptions of Hebrew names, occurring in Assyrian inscriptions, with the vowels used by the Assyrians represented by points. The Masoretic pointing of the Hebrew he thought it useless to set down.

אשדד	אַסְדֻּדֻ	שבאי	סַבָאָי		
ירושלים	אֻרְסָלִמָּה	שמרן	סָמֵרִנָה		
כוש	כָּסַ	אשקלן	אַסְקָלֻנָה	or	אַשְ״
כרכמש	קַרְקָמִס	דמשק	דִמַשְׁקֻ		
לכיש	לָכִס	משך	מְסֶךְ	or	מְשֶׁךְ

In all these Hebrew words the *Shin* is pointed to represent SH. When S was to be represented in a foreign name, Ezra, or some more recent editor, has invariably

substituted *Samech* for the *Sin* that was originally written. That SK was the original value of *Samech* is confirmed by the value of the Greek letter, which corresponds in figure and position to the latter; which is KS, and which was originally SK. It is also confirmed by the etymological relation of סֵף, "a bowl," with *σκάφη*, and סַף, a "sword," with *ξίφος*. What the Ephraimites in Judges xii. 6 said, when desired to say *Shibboleth* (which they, like the Assyrians, could not pronounce), must have been *Skibboleth*. It is SK, and not S, that a person would naturally utter, who was making an unsuccessful attempt to pronounce SH.

Prior, however, to the twelfth century B.C., the date of the earliest existing Assyrian inscriptions, *Samech* had acquired the secondary value of ST. In those forms of Assyrian verbs where a T was introduced after the first radical, when the first radical was *Shin*, *Samech* was used for the double letter. Thus we have אָסָכַן from שָׁכַן, representing *astakan*. Also when the affixes of the third person, all of which begin with S, were attached to nouns ending in T, we have *Samech* for the ST, which, according to a well-known Semitic analogy, would be substituted for TS. That K is particularly liable to be replaced by T, which is easier to be pronounced, appears from the languages of many Polynesian tribes, and from the first attempts at speaking made by children among ourselves. The passage of K into T appears in the verbal pedigree of the pronoun of the second person (fig. 11). It is evident that the T was derived from an original K in the three languages independently of one another. In the Egyptian, T was substituted in the feminine gender, the original harsher sound being retained for the masculine. In the Semitic languages, T was substituted for K in the independent pronoun, and in the preformatives and afformatives of verbs, K being retained for the possessive and objective affixes. In the Japhetic languages K has disappeared altogether, being everywhere replaced by a dental. The values of *Samech* were, therefore, originally SK only; from about the 13th century B.C., SK and ST, the latter gradually supplanting the other; and from the 6th century B.C., S.

Zayin expressed the sonant or softened sound corresponding to the second value of *Samech*, that is ZD; and from the 6th century B.C., Z.

Tsaddi expressed the strengthened sound corresponding to the above. After the 6th century B.C., it represented the Arabic *Sad*, and before that date, the combination of that letter with *Teth*.

Teth represented a strengthened TH. With the vowel *a* after it *Teth* is generally confounded, in Assyrian writing, with *Daleth*; and *Tsaddi* always with *Zayin*; but they are distinguished before the other vowels. Perhaps it may be fairly inferred from this, that *tha* was pronounced as in *that*, but *thi* and *thu* as in *thin* and *thumb*; always, however, with the peculiar Semitic strengthening of the consonant.

Qoph is another strengthened letter, bearing the same relation to *Gimel* and *Kaph*, that *Teth* bears to *Daleth* and *Tau*.

Heth must also have been a strengthened letter, being frequently substituted for *Teth*. It may be conjectured, but is scarcely capable of proof, that the letters to which it was related were *Ghayin*, pronounced as in the name of Gaza, and *He*.

Aleph is usually considered to denote the simple commencement of utterance, or the absence of any breathing or semivowel; and this certainly seems to have been its value in all the Assyrian inscriptions which are extant. If, however, we go back to the infancy of language, we shall see reason to think that *Aleph* had once a positive value. It expresses the preformative of the first person singular; sometimes alone, and at other times with a vowel, which is evidently one of connexion. As T represents the pronoun of the second person singular, and N that of the first person plural, so *Aleph* represents that of the first person singular; and this must have been originally something substantial, not a mere negation as at present.

The character which represents the preformative with the vowel *a* as a link of connexion, is that which as an ideograph denotes "water" (fig. 3). It represents other Hebrew letters as well as *Aleph*. In fig. 12 it has this value, that is אָ; but in fig. 13 it represents חָ; in figs. 14 and 15 יָ; and in fig. 15 it also represents ךָ. It is probable that the Hebrew words in which it represents initial *ya* were originally

pronounced with *wa*. This seems evident in the case of יין "wine," and of verbs like ישב. It would appear then that the letter *Aleph* passed into *He* and *Vaw*; and it is therefore natural to suppose that its original value was HW, which would easily do this. Indeed there is no sound which would be likely to be dropped that *Aleph* could represent except this, H, W and Y having other letters to represent them. In confirmation of this, it is to be observed that *mu* is the pronominal root of the first person in Accadian; and the Indo-European objective *me* implies the existence of a nominative *mu*, from which it would be derived as *te* from *tu*. The transition of *hw* into *m* is exceedingly common: see the annexed Table. The Japhetic form would then be *hwu*, the Semitic and Egyptian אְ or אָ, the vowel being unsettled. By adding *ku*, "here," to the primeval *hwu*, we have *kwu-ku*, changed for euphony into *hwáku* or *hwíku*, "I here." This became the Indo-European *iku*, and with the verb of presence *hwan-hwáku*, properly "adsum," and not used till a late period for "ego."

The character for "water" was in Accadian *hwa*; generally used in the plural as *hwa-hwa*. These were Japhetic forms; and from them we have the Indo-European *ahwa*, and from the singular form *ma*, *wa*, *wi*, *u*, all of which are in use. The Semitic *mi* and *mami* and the Egyptian *mu* are clearly connected with them.

The following is a list of the verbal pedigrees, several of them imperfect, which have been obtained by me. Of the numerals with which it begins, the Accadian words for "three" and "four" are less to be depended on than the rest. It is supposed that the second character in fig. 1 represents "a set of three," three bars or other objects connected by a string; that the Accadian name of this was the phonetic value of the character *ri*; while the Semitic word corresponding to this, *tal* (whence *talit* in the feminine), was a second phonetic value, as in fig. 10. The analogy of the numeral for "two" favours this view. It is supposed again that a rhombus or four-sided figure, of which the phonetic value was *ut*, represented the Accadian word for "four," as four small horizontal wedges represented the corresponding Semitic word. The equivalence in value of these characters seems probable, though it has not been demonstrated. Here again the analogies of Nos. 11 and 12 corroborate the pedigree.

No. 1. *ana* אָנָ "one," Ac. *hwana*; I.E. *hwan*; J. *hwan*.

No. 2. (See above), Ac. *mi*; I.E. *thwi*; J. *thmi*; E. *thui*; S. *thni*; Pr. *thmi*.

No. 3. (See above), Ac. *ri* (?); I.E. *tri*; J. *tri*; S. *tal*; Pr. *tar*.

No. 4. (See above), Ac. *hut* (?); I.E. *hwat-war* "four complete" and *ahwt-au* "two fours, *i. e.* eight;" J. *ahwat*, *hwat*; E. *afat*; Pr. *ahwat*.

No. 5. *iya* אָאֵ "five;" Ac. *hwihwa*; I.E. *hwinhwi*; J. *hwinhwa*; E. *thihw*; S. *hinth*; Pr. *hwinhw*.

No. 6. *as*; Ac. *has*; I.E. *sihs*; J. *sahs*; S. *sas*; Pr. *sahs*.

No. 7. (See above), Ac. *mu*; I.E. *mu*, *mi*; J. *hwu*; E. and S. אָ; Pr. *hwu*; I.E. *iku* "I here;" J. *hwiku*; S. *hwan-hwaku* "It is I here;" E. אן-אך; Pr. *hwa-ku* and *hwi-ku*, by euphonic change for *hwu-ku* "I here."

No. 8. Ac. *zdu*; I.E. *stu*, *sti*; J. *stu*; E. and S. כ and ח; Pr. *sku*.

No. 9. *a*, *ha*,*wa* אָ "water;" Ac. *hwa* and *hwa-hwa*; I.E. *ma*, *wa*, *wi*, *u* and *ahwa*; J. and Pr. *hwa*, and in plural, *hwa-hwa*; E. *mu*; S. *mi* and *mami*.

No. 10. *igh* אֵע "a house;" Ac. *hwigh*; I.E. *hwik*; J. and Pr. *hwih*; E. *pi*.

No. 11. *us* "a male;" Ac. *hus*; I.E. *mas*; J. *hwas*.

No. 12. *un* "a man;" Ac. *hun*; I.E. *man*; J. *hwan*; cf. No. 1; observing that the character for "one" is used as determinative of names of men. The connexion of the last two roots with איש and אנש is by no means impossible, though certainly not to be relied on.

No. 13. "A king," Ac. *man*; I.E. and J. *hwan*.

No. 14. "A lion," Ac. *lig*; I.E. and J. *lihw*; S. *lith*, *lavi*; E. *lavo*.

No. 15. "A jaw." Ac. *ka*; I.E. *kahw*.

To these might be added *sku*, the Accadian word for "a skin," and perhaps others. Now it must strike a person at first sight, that the above words are much better represented in the Greek, Latin, and Teutonic languages than in the Sanskrit. The

first on the list, and all those after the ninth have no representatives at all in Sanskrit; and of the eight which have Sanskrit representatives, it is only in the case of the numerals for "two" and "three" that they come anything like as near to the primitive Indo-European forms as the Classical or Teutonic representatives of these words. It thus appears that, contrary to what has been generally thought of late years, so far as the roots are concerned, the Greek, Latin and Teutonic forms approach the nearest to the primitive forms; while the Sanskrit deviates from them most.

Even as respects the verbal terminations, where the Sanskrit is more to be depended on, it appears that Bopp has given more weight to its testimony than it deserves. He considers the ST of the second person, preserved in English and German to this day, and found also in the Latin and Armoric preterperfects, to contain an unorganic addition; whereas it appears from what has been said that *m* and *st* are the commencements of the primitive Indo-European pronouns of the first and second persons singular. It is now manifest that the original declension of the Latin present was *reg-u-m, reg-i-st...reg-u-mus, reg-i-stis*. The *st* was reduced to *s* in the singular and to *t* in the plural; just as in the separate pronoun it was reduced to *s* in Greek and to *t* in Latin.

The increased value of the Greek and Latin forms given to them by this discovery renders it more than ever important to ascertain what they were in the earliest periods. It is known that while the Greek which has come down to us is written with an alphabet of twenty-four letters, the Greeks had at first only sixteen. It is therefore a question of great interest what these sixteen letters were; and in connexion with this it has to be considered how the Greeks originally wrote words which were subsequently written with the newly introduced eight letters. That the Greeks derived their letters from the Phœnicians is generally admitted; and both the names that are given to most of them and their forms prove that this is the case. The vowels of the original alphabet were the three Semitic breathings, *Aleph, He*, and *Ayin*. *Vaw* and *Yod* retained their original values, and represented the semivowels W and Y. Of the remaining seventeen Semitic letters there were six which represented either combinations of consonants, or those strengthened consonants which were peculiar to the Semitic languages. These six were rejected by the Greeks. The remaining eleven with the three vowels and the two semivowels constituted the original alphabet. These were the first twenty letters of the full alphabet, with the exception of Z, H, Θ and Ξ. An old Greek Scholiast expressly affirms that these were the sixteen original or Cadmean letters; and the fanciful theories of modern writers in England and on the Continent, in opposition to this statement, are unworthy of the slightest attention. Two different sets of four letters were added to the original sixteen in different parts of Greece. In certain districts the four excepted letters given above were added; but H was used as an aspirate, not as a long vowel. In other districts H was added as an aspirate, and along with it Θ, Φ, and X as compound aspirates. Prior to the introduction of H, its place was supplied by Σ, which was originally pronounced as a sibilant in the masculine article ΣO and many other words, and which afterwards retained its place in the word when an aspirate only was sounded there. This was the Σὰν κίβδαλον of the fragment of Pindar. About the time when H was introduced as an aspirate, the semivowels lost their original values, except in the diphthongs; and were used to express modifications of the original vowels E and O. The Æolians retained the semivowel for W, as well as the new vowel which the other Greeks substituted for it; but neither this additional letter nor the Koppa ever formed part of the regular Greek alphabet. At the time when Z and Ξ were first added to the alphabet, which must have been before 1000 B.C., their values were σδ and σκ respectively. By combining together the letters added in different parts of Greece, an alphabet of twenty-two letters was formed. The values of Z and Ξ having been changed from those just stated to δσ and κσ, Simonides added a twenty-third letter, ϖσ; and he then completed the alphabet by adding the long Ω at the end; changing at the same time the value of H from an aspirate to a long vowel.

It appears from what has been said that in the earliest Greek writing the vowels E and O were used to express what were afterwards divided into two vowel sounds; the former comprehending E and I, the latter O and Y. In like manner, the conso-

nants K, Π and T were used to express not only the sounds that were afterwards expressed by those letters, but also those that were afterwards expressed by X, Φ and Θ. It is important to attend to this; as the mode of spelling which prevailed before this distinction was made, was for the most part retained in roots and even in suffixes of derivation. Thus *πέντε, πέμπτος* might be intended to express not only the words which those letters would represent when the alphabet was completed, but also *Φίνθε, Φίμφθος*, and so in other instances. Analogy leads us to think that if the twenty-four letters had been all in use when the language was first written down, these words would have been written in the last-mentioned mode.

In these instances the ancient spelling has been preserved, but the pronunciation which it suggests has been changed. In other instances the spelling has been altered; and there is particular need to attend to that change of spelling which was occasioned by the dropping of the semivowels and the change of Σ to H, and this again to a sign of aspiration which was dropped in the middle of a word, and not always expressed at the beginning of one. The examples of *ὁ, ἡ*, originally ΣΟ, ΣΙΑ, then HO, HIA, or HA, and of *ἁνδάνω*, originally ΣΥΑΝΔΑΝΟ, will sufficiently illustrate what is meant.

On the supposed Biblical Names of Baalbec, and on the position of Baalgad. By JOHN HOGG, *M.A., F.R.S., L.S., R.G.S. &c., Foreign Secretary of the Royal Society of Literature.*

The author began this communication with some remarks on the vast interest which has recently become attached to the geography, both historical and physical, of the Bible; especially since the important geographical and topographical excavations and discoveries in ancient Assyria, and other parts of the East, have thrown fresh light upon many portions of Scripture. Also, as regards the *cartography* of Syria and Palestine, much had been done of late years by Russegger, Robinson, Porter, Van de Velde, and the officers of the American Survey. The author said, that notwithstanding these great additions to science, he felt satisfied that much still remained uncertain respecting the natural positions of many of the valleys and river-courses in both Lebanons, a more correct knowledge of the heights of the chief mountains, the magnetic influences, and certain meteorological phenomena.

Considering that *Baalbec* had been so long known to travellers and artists, and its magnificent ruins so often visited and described, it was a remarkable fact that its *Biblical name* remained at this day undetermined. And it was further remarkable, that history has not preserved the name of its founder, or recorded in what year of the world it was begun to be built. As a Roman colony at the commencement of the Christian era, under the name of "Heliopolis," it bore the title of "Julia Augusta," derived from its benefactors, Julius and Augustus Cæsars.

The author then showed that it could not answer in geographical details to Baalath, or Baal-Hamon, or Balamo, or Baal Hermon, or Baalah, or Baalgad, of the Scriptures. Dr. Robinson of America imagines with much probability, that the prophet Amos, in chap. i. v. 5, alluded to Baalbec (*Heliopolis*) and its idol-worship, where he mentions "the plain of *Aven*," or as it is given in the margin of the Bible, "*Bikath Aven*." This would seem to refer to the plain of Cœlesyria, or the *Bukaa*, meaning a "valley," which lies between the Lebanons, or the range of Libanus, and that of Anti-Libanus. Mr. Hogg observed that this 'allusion' had long ago occurred to the traveller Maundrell, and to Dr. Wm. Lowth. The Septuagint translators having rendered the Hebrew word 'Aven' by *On*—the *Heliopolis of Egypt*—thought the same. As this word 'ΩΝ is supposed to mean in Egyptian the *sun*, so the Septuagint rightly translated it *Heliopolis*; consequently *Bikath Aven* would signify the *Bukaa On*, or 'plain of *On*;' that is to say, the plain or valley of Heliopolis.

The author, in this supposition, agreed with those writers, and he further remarked that the word *Baalbec* has the same meaning in Aramaic or ancient Syriac, viz. the "Sun-city."

In the next place, as to the geographical *position* of Baalgad, Mr. Hogg, having demonstrated from the descriptions contained in Scripture, that it could not coincide with the site of Baalbec, as has been strongly urged by many authors, considered

that Dr. Robinson's supposition of Baalgad having been "no other than the secluded grotto," *Panium* near Paneas, now called *Banias*, was quite untenable. He, on the contrary, conceived that the ancient and long-lost *Baalgad* must have stood either in Wadi E' Teim, or in a neighbouring smaller valley of Lebanon, on the west of, and under Mount Hermon, named at this day the 'Mountain of the Chief,' or *Gebel E' Sheikh*. Indeed, he said that a hope might be entertained that among the numerous ancient ruins and temples still remaining in the Wadis near the Lebanon, some vestiges of *Baalgad* might yet be discovered, when more careful explorations shall have been made, in the secluded western gorges adjacent to the noble Hermon.

Mr. Hogg pointed out the supposed position of Baalgad, as it accorded with the accounts of Holy Writ, on a sketch map which he had coloured and drawn on a scale eight-times enlarged, from a part of Kiepert's "New Map of Palestine and Cœlesyria," 1856, extending from nearly 33° 14′ to 34° north latitude, and from about 35° 35′ to 36° 11′ east longitude; and he also explained from it the sites of other Biblical localities, as well as the present courses of the principal rivers in that portion of Syria.

On the Cause of the Mild Winter Temperature of the British Islands. By T. Hopkins.

In this paper the writer combated the opinion that the mild winter temperature of the north-western part of Europe is attributable to the warm ocean stream that flows from the Gulf of Mexico into the Atlantic Ocean. He denied that the mere contiguity of a warm current makes the adjoining country warm. In support of this, it was shown that the parts of America close to the Gulf and the warm stream, are not warmed by them. On the contrary, Louisiana and Florida, notwithstanding their vicinity to the warm water, were shown to have cold winter climates; and this character attaches to the sea-board of America that extends parallel with the Gulf-stream.

It was shown that Dove's Isothermal line for the month of January, of 50° Fahr., passed over the 45° of latitude in the Pacific Ocean, but that it descended to the 32nd degree near the Gulf of Mexico, and when crossing the warm Florida stream the line rose but little; yet as it passed to the middle of the Atlantic it ascended to the same latitude that it passed over in the Pacific, thus showing that it was as cold over the warm stream in a southern as in the middle of the Atlantic in a northern latitude. Extracts were given from Dr. Scoresby's paper on the temperature of the northern Atlantic, in which it was shown that the cold current which flows from Baffin's Bay, and passes the island of Newfoundland, intervenes between the Gulf-stream and the ocean to the north of 40° of latitude, stopping its progress east in that latitude. These facts, it was contended, showed that the warm water of the Gulf-stream flowed, as described by Humboldt, towards the Azores, and therefore could not warm the north-west parts of Europe.

It was stated also that an ocean current runs from 7° of south latitude along the Brazilian and eastern Patagonian coasts, but that it no more warms those countries than the Gulf-stream does the adjacent parts of America, all these countries being dry and cool in the winter season. It was contended that the mild winter climate of the British Islands was due to copious condensation of vapour brought from the surface of the Atlantic Ocean. This vapour is condensed freely in the winter and warms the atmosphere, the vapour giving out its heat of elasticity to the air, this warmth extending to other parts in proportion to the amount of vapour condensed. The Isle of Skye in Scotland is warm in the winter, and it is recorded that more rain had fallen in that island in the single month of January than falls in Paris or London in a year.

Instances were given of sudden changes of winter weather from cold to warm, in Manchester and Paris, under circumstances which proved that much heat was brought to those parts in vapour. Other parts of the world, distant from the tropics, were also pointed out, which were rendered warm in their winters by condensation of vapour, and not through the contiguity of a warm ocean. The north-west coast of America, up to the latitude of 60°, has as warm a winter climate as the western coast of Europe in the same latitudes. And Western Patagonia and Cape

Horn, extending from 40° to 54° of latitude, have very warm winters, although the ocean that laves their shores is cold; but the winter rains are heavy and constant.

The general conclusion drawn in the paper was, that the British Islands, as well as many other countries in cold latitudes, but which have warm winters, have their winter climates determined by condensation of vapour.

On the application of a Decimal Scale to the construction of Maps. By W. Hughes, *F.R.G.S.*

The writer urged the desirability of using a system of decimal scales, not merely in the case of the national surveys undertaken by the governments of different nations, but as a principle which might with advantage be adopted in *all* maps, of whatever size, and which would prove especially valuable in those designed for educational purposes. The Ordnance Map of Great Britain contrasts disadvantageously with the national surveys of other countries, in the fact that, of the different scales used from time to time in its construction, no one of the number bears a decimal ratio to the earth's quadrant. In the case of ordinary maps, where uniformity of scale is unattainable, the various scales employed might yet always bear a decimal ratio to one another. In proof of this, the paper was accompanied by a series of projections, such as might be used for the various maps embraced within an ordinary Atlas. Thus, supposing Europe to be drawn on a scale of $\frac{1}{10,000,000}$, Asia and Africa would be delineated on exactly half that measure, or $\frac{1}{20,000,000}$; North and South America on a scale of $\frac{1}{15,000,000}$. A scale of $\frac{1}{2,500,000}$ would correspond to the required dimensions for a map of the British Islands, and also for maps of France, Spain, Prussia, Austria, Turkey, Italy, &c. Switzerland, Holland, Belgium, Greece, and other countries would be on a scale of $\frac{1}{500,000}$. The same principle might of course be adopted in the case of divisional maps, such as the counties of England, for example. Thus if the allotted size would allow of Surrey being drawn to a scale of $\frac{1}{100,000}$, Lancashire (a larger county) might be on $\frac{1}{200,000}$ of the natural measure, and so on.

The writer pointed out the advantages attendant on the use of such a system, in the facility of comparison between different maps, and in the more definite character which might be given to the features which the maps drawn on progressive scales would embrace. For educational uses especially, the value of attention to such points can hardly be over-rated. It is from maps that our ideas of distance and magnitude, in respect of geographical objects, are chiefly derived in early life, and no after-teaching will counteract the erroneous impressions that are often imbibed at that period. Proportionate distances and magnitudes, referred to an easily-comprehended standard, are the basis of all sound geographical knowledge.

On Routes from Lima to the Navigable Branches of the Amazon, with Notes on Eastern Peru as a field for Colonization. By Santiago Jackson.

The first part of this paper was on some geographical details of no great interest. On the subject of colonization, it was stated that a colony of 200 or 300 Europeans desirous of settling on the eastern slope of the Amazon, ought to arrive at Lima in April or May, and have a depot of food provided at their destination beforehand, enough to last about four months, at the end of which time they would be able to live on the produce of their fields. Neglect of this precaution has caused the failure of several attempts at colonization, for the natives cannot supply any unexpected demand.

The resources of the Amazon territory are unsurpassed in the world. It will produce any quantity of sugar, coffee, tobacco, indigo, cochineal, rice, and cotton. The latter is better than any grown in the United States, except the Sea Island. Cinchona bark, dye-woods of various kinds, india rubber, and gutta percha have been discovered. Cedar trees of enormous size abound; but the forests are encum-

bered by dense brushwood, through which one must cut one's way. Savannahs are found in a few places. Gold, silver, copper, iron, sulphur, cinnabar, coal, and other minerals are known to exist. The rivers swarm with fish.

The climate varies in different localities; it is healthiest highest up the rivers. The country in its wild state is liable to low intermittent fevers, which however in great part disappear when it is cleared.

The Peruvian Government is prepared to make large grants of land and give extensive rights of self-administration to European colonies in the valley of the Amazon.

A short Statement of Discoveries in Southern Africa. By the Rev. Dr. LIVINGSTONE.

On the Sources and Origins of Human Races and their Languages, more especially the Celtic. By W. MACDONALD, *M.D.*

On the Final Arctic Searching Expedition. By CLEMENTS R. MARKHAM.

The search for Sir John Franklin's expedition has been continued with untiring energy until no less than 21,500 miles of coast-line has been examined; and the search for traces of the missing ships has been contracted within those narrow limits bounded by the western shores of Boothia, King William's Island, and the space occupied by a strait or deep inlet from Osborn and Wynniath's farthest, to Victoria Channel.

Thither the Expedition commanded by Captain M'Clintock, the father of Arctic travelling, has proceeded, to solve the mystery which has so long hung over the fate of our gallant countrymen.

His intention is, after ascertaining the safety of the abundant stores of provisions left on Beechey Island and in Leopold Sound, first to examine the state of the ice in Peel Strait, and his prospect of success in this direction appears to be very hopeful. But should he fail in his endeavour to force his way down it, it is almost certain that he will have been able to reach such a position down Prince Regent's Inlet, as to complete the search by travelling parties in the ensuing spring.

The Expedition which sailed last July, differs from any preceding one, from the important fact that its commander knows the exact spot to which his search should be directed. He has gone forth, single-handed, to complete the search for this most heroic body of men, with the determination of clearing up the mystery which has so long hung over their fate, and of crowning his long and weary labours with success.

It is satisfactory to find that an officer who has searched from the very first, in every expedition, through Lancaster Sound, will now, in all probability, have the glory of completing this deeply interesting work; and I am certain that everyone here will unite in wishing him all the success that his noble perseverance so well deserves.

On the Macrocephali of Hippocrates. By Dr. MINCHIN.

The singularity of cranial outline which constituted so remarkable a character in the appearance of the ancient Macrocephali as to have induced Hippocrates to assert that no other nation had heads in the least resembling them, presents us with a problem, which, however curious and interesting as a matter of speculation and inquiry, is nevertheless beset with difficulties of a practical nature when we come to examine and compare the different statements to be found in the works of Strabo, Pliny, Mela, and others, regarding this singular people.

The author of the paper referred to the various accounts of the "long-heads," as given by the several ancient authors. From these he endeavoured to show that they were probably not a distinct race or tribe; that, however, in a particular district near the south-east of the Black Sea, a certain form of cranial elongation appeared, and that the individuals so constituted were possessed of mental endowments of a peculiar kind. Thus, Hippocrates says that "they were considered most noble who had the

longest heads;" and Mela describes the long-heads as being "*minus feri*" than the other tribes in their vicinity. The author conceives that a recognition of this mental superiority may probably have suggested originally the practice of infantile skull-compression, the people ignorantly supposing that the elongation could be imitated by art and would be followed by a corresponding improvement of the mental capacity. A remarkable passage in the eleventh Book of Strabo lends likelihood to this supposition. In this passage, a certain tribe is said to have anxiously endeavoured to appear excessively long-headed and to have *foreheads projecting* over their beards.

The author commented at some length upon statements in the writings of Tschudi, Wagner, Meyer and Rathké, all of whom have endeavoured to prove that the Macrocephali had heads of the *acuminated* form which is found among those of the Peruvians. In opposition to these views, he adduced the case of the first Macrocephalic head which had been found in the East, namely, that sent by Asche to Blumenbach, and figured by the latter in the 'Decades Craniorum.' This head was elongated *antero-posteriorly*, and was of a wholly different stamp from Peruvian pointed heads. The author proved by a reference to numerous instances of an exactly similar head-form, that this elongation was a natural shape. He entered into a brief anatomical description of the cause of the elongation of these heads, and exhibited to the Section some well-marked examples; one of these was the skull of a child aged three and a half years, whom he had seen during life. In this cranium could be seen the central vertical point of ossific origin, from which sprang originally a single os bregmatis in place of two parietals. The absence of an interparietal (or sagittal) suture at this early age, was considered by those present as a remarkable feature of this cranium. But in fact all the long-heads with overhanging foreheads have this same constitution of the vertex. It is this original central ossification which gives a fixed character to the shape of the middle region of the head, and precludes the enlargement of the skull in a transverse direction during the period of growth; the skull therefore is obliged to enlarge excessively in some other direction wherever the open sutures permit, and the result is a decided elongation fore-and-aft. In the organic kingdoms it has been observed that occasionally very singular varieties will occur, which seem to be almost a distinct species, capable of reproducing similar varieties; these, however, disappear, and afterwards reappear sporadically at irregular intervals. Now, in several countries of Europe within comparatively few years, many instances of skulls have been observed, having the anatomical characters described above,—the elongated shape, overhanging forehead, vertical ossification. The author conceives that it is more consistent with the principles of cerebral physiology to suppose the Macrocephali to have been thus constituted, than to say that because Hippocrates has mentioned the custom of skull-compression in connexion with these people, their heads must have been necessarily acuminated; for in the treatise on injuries of the head, by the same venerable author, pointed heads are called by the Homeric term *φοξοί*.

The author conceives that the fact of several skulls of the latter shape having been found, some at Kerch, and one at Gräfeneck, does not tend to prove the prevalence of an artificial custom in later times (*e. g.* among the Avars and Huns) in that part of the world, for the entire number of these heads which has as yet been found does not exceed six, and not one of them has been found *within* a tumulus or accompanied with other bones of the skeleton, while in several sepulchral mounds, *near* to which pointed heads have been found, entire skeletons have been discovered, but with normally-shaped skulls. The most recent investigations have shown that the stray, solitary instances of acuminated and compressed heads found in Europe, may all be referred to one and the same period, namely that of Charles V.; they have been brought over from Peru and afterwards cast adrift. These heads therefore throw no light whatever upon the probable shape preserved by the heads of the so-called race of extinct Macrocephali.

In fine, the author thinks it highly probable that the crania of the earliest Macrocephali possessed the same shape as that described by Blumenbach in the 'Decades Craniorum,' and that the reappearance of this form as a sporadic phenomenon in many parts of Europe in the present day, gives support to this hypothesis; moreover, this shape has been found in many living instances to be associated with a superior degree of intelligence. The leading characters of these heads are:—great antero-

posterior length; smallness of biparietal measurement, with apparent compression of the sides; roundness and projection of frontal region; absence of sagittal suture; this last being the determining cause of all the other peculiarities. It may easily be imagined how this flattened appearance of the temporal regions may have suggested the custom of compression spoken of by Hippocrates.

On the Remains of early Stone-built Fortresses and Habitations in the County of Kerry. By George V. Du Noyer, *M.R.I.A.*

In this paper attention was directed to a class of Celtic antiquities hitherto but slightly noticed by archæologists, and in this instance to an extensive group of those buildings discovered by the author in the summer of 1856, and which occupy a line of three miles in extent along the southern tope of Mount Eagle; they amount to more than seventy in number, and he considered he was justified in calling this remarkable collection of edifices erected in pre-historic times, "a Celtic city."

The buildings consisted of massive stone houses of dry masonry, variable in their internal ground-plan, which was sometimes circular or elliptical, or a waved-oval, or semi-oval, or semicircular, or square; and in one instance, north of Kilmalkedar, the house consisted of two apartments, one square and the other circular, both connected by a straight passage; when perfect, these buildings terminated in a dome-shaped roof; the stones, overlapping each other on the wall, rose till one stone closed in the top. Groups of such houses are often surrounded by a massive stone wall, as if intended for warlike purposes, or they occur singly of one, two, or three separate apartments, more or less circular in plan, and evidently intended for residences merely; some are yet quite perfect, but generally the roofs have fallen in. One of the most important of the former class is called "Caher-na-mactirech," or the stone Fort of the Wolves, and it presents many peculiarities of architecture which renders it unique of its kind. Of the latter class he instanced a triple-chambered building, waved oval in plan, and 80 feet in its longest diameter; this is known as "Caher-fada-an-doruis," or the long Fort of the Doors.

The highest authorities on Irish Archæology attribute the erection of such buildings as are described in this paper to the Firbolg and Tuatha de Danann tribes, who inhabited this country prior to the introduction of Christianity.

In conclusion, the author dwelt on what must have been the habits as well as the probable social condition of the people who erected such rude and solid buildings, which, from their sequestered position and other favouring causes, have been preserved through the lapse of ages to the present time.

On the Sea of Azof, and the Sivash or Putrid Sea. By Capt. S. Osborn, *R.N.*

Abstract of the Report of James Anderson, *Esq., Chief Factor of the Hudson's Bay Company, commanding a Searching Party that descended the Great Fish River in quest of the Remains of the Crews of the 'Erebus' and 'Terror' in* 1855. *By* Sir John Richardson, *R.N., F.R.S.*

The author gives the details of his survey, illustrated by a map of a new route between the Mountain Portage on the shores of the Great Slave Lake and the Lake Aylmer of Sir George Back, comprising about 200 miles of water communication, interrupted by rapids and short portages.

On Lake Franklin, near the mouth of the Great Fish River, Mr. Anderson came to an Eskimo encampment of three tents. The inmates were in possession of various articles that had belonged to Sir John Franklin's party, viz. a letter-clip bearing date 1843, fragments of elm, oak, mahogany, and white pine boards, some of them painted white. From the want of an interpreter it was very difficult to obtain correct answers to queries from these simple and friendly people. Printed books were shown to them and pieces of written paper, with the offer of large rewards for anything of the kind, but they signified that they had none. The women exhibited much intelligence, and apparently a ready comprehension. They made signs by pressing the

stomach inwards, pointing to their mouths, and shaking their heads piteously, that these things were obtained from a kayack of a party who had died of starvation. Two men of the same tribe were met further down the river, but nothing more was learnt from them.

Mr. Anderson remained three days on Montreal Island and thoroughly explored every part of it. The spot where the expedition boat had been cut up was on a rocky ridge at its north-eastern extremity. The ground there was strewed with shavings of wood, ends of plank, &c., evidently cut by the natives. On a piece of board that was painted black, the name "Erebus" was carved. Small pieces of rope containing the coloured dock-yard threads, pieces of bunting, &c., were lying about. There being many Eskimo câches in the neighbourhood, they were opened, and in them were found, besides stores of seal oil, blacksmith's tools, a tomahawk, a chain-hook, a fragment of an unwrought iron bar, a bundle of ash sticks, being parts of snow-shoe frames with "Mr. Stanley" carved on one, together with some pieces of hoop-iron, parts of instruments, a bit of cane, and a piece of the leather of a backgammon board, but not a scrap of paper nor a human bone. Every mound was examined in search of graves, but without success. Both coasts of the peninsula, from Elliot Bay northward, were minutely searched, but nothing more was found except a bit of cod-line and a rag of striped cotton on Point Ogle. Maconochie Island was also carefully traversed, but the state of the ice hindered the canoes from crossing to Point Richardson. On the return, part of the eastern shores of the estuary was also examined, and the Eskimos at Lake Franklin were again visited. They were now assembled to strike their tents and move elsewhere, and the strength of the party was seen to be five men, three women, and twelve lads and children. Mr. Anderson spread all his trading stores before them and offered the whole for books or papers, but they signified that they had none, and opened all their câches to show what they actually had. In the câches were found an oval frying-pan, a chisel, a broken hand-saw, a piece of a metal thermometer-scale, and part of an ivory rule. Most of the paddles of the party were made out of ash-oars.

These people made Mr. Anderson comprehend that they had not seen the ships or great kayacks, but that they had heard from others of their being wrecked, and that the crews had all died of starvation. Mr. Anderson, judging from the quantity of drift sand on Montreal Island and on the adjoining peninsula, thought that if the expedition perished there, their bodies would be covered by that material.

On the Inhabitants and Dialect of the Barony of Forth in the County of Wexford. By the Rev. CHARLES RUSSELL, *D.D.*

On the Routes pursued by Herren Hermann, Adolphe, *and* Robert Schlagintweit *in India, the Himalayas, Tibet, and Turkistan. By* ROBERT SCHLAGINTWEIT.

This paper was introduced by a short account of a demi-official nature regarding their mission to India. Mr. Schlagintweit mentioned in the highest terms the labours of their predecessors in scientific researches in India, particularly amongst many others, Buist, Cunningham, Everest, Gerards, Hodgson, Hooker, Oldham, Strachey, Sykes, Thompson, Waugh, &c.

In reference to their official position, they were particularly indebted to Col. Sykes, as well as to the Royal Society under Gen. Sabine's directions.

In 1854 they reached India, and passed from Bombay to Madras, through Central India, each by different routes, making geological, geographical, and other scientific investigations as they proceeded. On their sea voyage previously, they had made observations as to the specific gravity of sea-water, and also as to the currents of the sea, and continued these in the voyage from Madras to Calcutta.

On arriving at Calcutta in the beginning of 1855, Mr. Hermann Schlagintweit set out for the northern provinces of Bengal, and, having reached Sikkim, continued his researches all along the Himalayas, with a view of ascertaining their height and geographical position. To the west of Kunchinjinga he met with a remarkably high mountain, mentioned in a letter to Baron Humboldt (July 10, 1855, summit of

Phulloot); this is the same mountain, exceeding 29,000 feet English, which, independent of Mr. Hermann Schlagintweit's measurements, was signalized in 1856 by Col. Waugh, from the Proceedings of the Trigonometrical Survey, as the highest mountain, and was called by him Mount Everest, after his distinguished predecessor.

This is the highest mountain in the world at present known, being considerably over 29,000 feet above the level of the sea. The natives have two names for it: one of them, Gaurisankar, which is mythological, is to be found only in the Nepaulese territories; and the second name, Chingopanmari, is that by which it is known among the people of Tibet to the north. The name Deodunga, which was mentioned by Mr. Hodgson occasionally in connexion with this peak, was not the name of this mountain, but of a small mountain some 8000 feet high, which lies in the same direction when seen from Katmandoo.

It is very remarkable that the signification of Gaurisankar, a Sanscrit word, is identical with the Bhutea word Chaura Cha ri, probably the highest peak of Bhutan proper.

Gauri Chanca means the female deity.

Sankar Cha, the male god, Sankar especially being a form for Shiva.

Ri, in Bhutea (mountain) is the only part not represented in Gaurisankar.

After leaving Sikkim, Hermann, having examined a part of the Bhootan Himalayas and Upper Assam, returned to Calcutta by the Brahmapootra and the delta of the Ganges. Adolphe and Robert left Calcutta in March 1855, and after passing through the north-western provinces, reached Nainital, and then went to Milum, and thence to Tibet.

They investigated the geographical and other features of the country as they went on; the principal of which was the alluvial deposit along an immense valley, the largest probably in the world. In this valley the Indus and the Dihong both take their rise, and flow in opposite directions, but nearly in one line, for hundreds of miles, their origin being separated only by a small rise in the surface of the valley. They then went to the Ibi Gamin, and having encamped on a glacier there, at the height of 19,220 feet, on the evening of the 18th of August, they on the 19th of August succeeded in reaching the flanks of the Ibi Gamin (called Kamet by Capt. Strachey), at the height of 22,260 feet, the greatest height which had ever been attained on any mountain. They returned to the plains of Hindostan by different routes, each pursuing his special inquiries.

Mr. Robert then entered into some details respecting the operations during the next cold season. He went to Central India, where he visited the plateau of Amarkantak, which is only about 3300 English feet above the level of the sea, though it is erroneously supposed to be 8000 feet. Four rivers take their rise in the neighbourhood of this plateau, the Nerbudda, the Soane, the Fohilla, and the Mahanaddy.

Mr. Adolphe went through Central and Southern India down to Trichinopoly, visited the Nilgherries, and returned afterwards by Madras and Calcutta to the North-west provinces.

The three brothers again met at Simla, previous to commencing the operations intended for the summer of 1856.

Mr. Adolphe, on leaving that place, crossed the Himalaya, went over Tibet, Baltistan, and visited the interesting spot where several mountain crests meet, and the Hindoo Koosh joins the range lying to the north of India. He then returned to the Punjab through the valley of Cashmere.

MM. Hermann and Robert proceeded to Ladak by different routes. Under good disguises, they were enabled to penetrate into Turkistan proper, by crossing the Karakoroom and the Kuenluen mountains and descending into the great valley of Yarkand, a region never visited before, not even by Marco Polo. It is a vast depression of between 3000 and 4000 feet, separating the Kuenluen, on the northern frontier of the Himalaya—Tibetan system of mountains—from the Syan Chane, or the mountains of Central Asia, on the southern border of Russia. They then returned to Ladak, and entered the Punjab by different routes through Cashmere, where they again met all three, for a short time, at Rowulpiodee.

From there, their routes were the following ones:—

After a two years' negotiation, Mr. Hermann was, at the commencement of 1857, admitted into Nepaul, where he determined the altitudes of Mount Marhipoorha and

Mount Yassa, which have hitherto been vaguely called the Dhawalagery, which means nothing else but "snow crests," and is applicable to all snow-capped mountains.

Mr. Robert proceeded to Bombay through Scinde, Kutsch and Guzerat, where he surveyed the chain called the Salt Range, and determined the changes effected in the course of centuries in the bed and direction of several rivers. Before returning to Europe, he stayed a month in Ceylon.

Mr. Adolphe visited various parts of the Punjab and of Cabul. He intended to return to Europe in a few months, when by the spreading out of the revolution in India this became impossible. He seems to have made the best of his time by returning on a more western route than his brothers to Yarkand, from where the last indirect news which have reached Europe are from July.

On some Human Races in India and Upper Asia. *By* Hermann Schlagintweit.

The principal races of India are,—

1. The *Aborigines*; they live now in various mountainous parts of India, for example in the small mountains in the south of Bengal, in Central India, in the Nilgherries, &c.

2. The *Brahmins* and their descendants by intermixture with original tribes of India.

3. The Mohammedan *Mongols*, also crossed with the tribes 1 and 2.

4. The Buddhist *Mongols*, who have kept themselves very pure.

5. The *Fetish-worshipers*, likewise Mongols, and in the mountains between India and Burmah, almost as savage as the inhabitants of Australia.

1. The *Aborigines* of India consist in India itself of the following tribes:—*a.* God. *b.* Bheels. *c.* Kols. *d.* Santals. *e.* Tudas.

Another very numerous series of tribes, which are very similar to them physically, occur in Tartary, along the entire foot of the Himalaya.

By the remarkably dark colour of their faces, by their thick, protruded lips, they approach very closely to the type of the Africans, especially in the lower part of the face. They are essentially distinct from all the other tribes of India. Their forehead is, however, usually far better formed than in the Africans. With regard to the separate parts of the skeleton also, these races are furthest removed from the Europeans.

They are at a very low stage of civilization, and many of them have no written language, at least at present. Their clothing is very miserable, consisting of a cloth wound round the loins; they have no covering for the feet, and, what is peculiarly characteristic, they alone, amongst all the inhabitants of India, are able to withstand the influence of the sun without any covering for the head. They live by breeding cattle, and by miserable husbandry in the uncultivable wildernesses of Central and Southern India, in small huts formed of twigs and branches of trees, which they have erected in open places which occur amongst the jungles. They also alone can endure the miasmatic air which is evolved during the rainy season in their forests, and which is so dangerous to all the other races of India.

Their natural shyness and timidity has been greatly increased by the haughty contempt with which they have been treated by the castes of the other inhabitants of India; not unfrequently they are seen to take flight into the thickest wilderness at the first glance of a European.

2. The second principal class is formed by the *Brahmins* and their descendants, which are now best understood under the names of the Indian castes.

The Brahmins and their descendants are divided into the four following great groups:—1. Brahmins. 2. Tschatrya, Chatrya. 3. Vhaysias. 4. Sudras.

Each of these four principal groups includes a great number of castes, produced in the following manner:—

When the Brahmins, who we will regard as a homogeneous tribe when they came from the Himalaya to India, mixed with the tribes of the Autochthones of India, namely with the Gõds, Santals, &c.; their posterity formed a great number of castes, as the descendants of a Brahmin, with every other tribe, were regarded as quite new castes. Moreover, the number of castes was increased by the Mohammedan Mon-

gols who subsequently penetrated into the country, and their strict separation and nomenclature was enjoined and sanctioned by religion. As soon as a caste contained a considerable number of members, these intermarried almost exclusively amongst themselves alone, and followed a mode of life which was very different not only from that of the other groups, but sometimes even from that of their allied tribes. The altered mode of life continued for centuries, and the strict separation from the other castes have exerted so essential an influence upon the physical character and development, that at the present day castes which, ethnographically considered, belong to *one and the same* group, have become so essentially different, which was not the case at first, that it is often impossible, without tracing the historical formation of the castes, to determine with certainty the degree of their connexion from their physical characters alone.

As one of the most strongly marked examples of the influence which the mode of life exerts upon the physical development, we may refer to the three principal divisions of the Brahmins:—the *Cashmiri Brahmins*, who eat flesh; the *Kannanj Brahmins*, who live upon vegetable food; and the *Bengali Brahmins*, who enjoy the privilege of having an unlimited number of wives, even from the lower castes. The *Cashmiri* Brahmins are of powerful frames, have pale faces even when they have lived for generations in India, and are very intelligent and active. [Many of their colonies still occur in Delhi and Lucknow; some also in Nepaul.]

The *Kannanj* are weak, destitute of all physical and mental energy, and have a peculiar formation of the head.

The *Bengali* Brahmins are ambitious and intellectual, but not unfrequently distinguished from the others by the want of an upright and open character.

As among the Brahmins, great differences have often formed nearly related castes in the other groups also.

I may mention, as a peculiarly characteristic example, the three nearly related castes of the Mehtars, Dhobis and Tsamars, belonging to the group of the Sudras, which are now most clearly distinguished both in the formation of the face and the structure of the body.

3. The *Mohammedan Mongols* are to be regarded as the third principal race of the inhabitants of India; they have penetrated into India from the Asiatic countries bounding India to the north-west, over the Hindoo Coosh and through Affghanistan. In their religion they were Mohammedan, perhaps divided into various sects, but at all events free from the prejudices of the Indian castes. As soon as they had mixed themselves with the Indian tribes, their descendants, in accordance with the Indian ideas in general, were raised into a new caste, and now all Mohammedans are universally divided into castes, to which they hold strictly, although these are neither founded in their religion, nor in the institutions of the countries from whch they came as conquerors. The Mohammedans in India fall into the following castes:—Moghuls, Pashans, Sayyads, Shaiks.

Simultaneously with the intermixture of the various peoples hitherto referred to, a new language, the Hindostani, was also formed, containing elements from all their languages, especially from the Sanscrit dialects, the Arabic and Persian. This has assisted essentially, so far as it has been diffused, in softenidg the original separation of tribes still speaking differently, such as exists in America, into the slighter distinction of castes speaking the same language. In those parts where Hindostani has not been diffused, for example in the mountains of Central and Southern India, in the mountains which separate the valleys of the Brahmaputra and Irawaddy and in the parts of the eastern Himalaya inhabited by Mongols, the difference of language has given the diversity of races a very different and far more definite type; in these places even small tribes have been developed, who cannot understand one another's language, and are also distinguished far more strongly both physically and in their religious and political code, than the corresponding castes of the same physical relationship who speak Hindostani.

4. The *Buddhist Mongols* constitute the fourth principal class. This class includes a great number of tribes, of which I may cite the following as the principal. In the eastern Himalaya, in Bhutan and Sikkim, the *Bhutias* and *Lepchas* predominate. In the northernmost, and at the same time highest parts of Nepal also, there are many Mongol tribes on this side of the water-separation of Tibet. In the Western Himalaya

they are no longer pure, but mixed with Brahmin races, and if possible distinguished into castes even more than in India itself. The principal seat of the Buddhist Mongols, which may be regarded as a great and perfectly homogeneous tribe, is in Tibet, where they have retained their religion unchanged for centuries perfectly free from Indian castes; it is only in a small portion of Tibet, the westernmost, that the Buddhists have been converted to Islam.

In Central Tibet itself, when the great caravans from Russia came through Turkistan as far as Cashmir, a mixed race between the Tibetans and the Northern Mongols had been formed, which is called Argon: they are Mohammedans.

5. The half-savage, nearly naked races in the mountains to the east of the Brahmaputra, constitute another group to be specially referred to. From their most general characters they belong to the Mongol race, but possess little similarity even amongst themselves in language and bodily structure. The few religious ideas of the lowest kind which they possess, are also very different in the various tribes.

6. For the sake of completeness, we have still to mention, as perfectly foreign races dwelling in India, besides the Europeans and their descendants of mixed race, the *Parsis* and Jewish settlers, some of them very ancient, a few *Sidis* from Africa, and *Armenians*, nearly all confined to the west coast of India.

On the Influence which Physical Characteristics exert upon the Language and Mythology of a People, as a means of tracing the affinities of Races. By Professor W. K. Sullivan, *M.R.I.A.*

Observations on Vancouver Island.
By Kenneth Leith Sutherland, *R.N., Barrister-at-Law, F.R.G.S. &c.*

This island, situated between the parallels of 48° 19′ and 50° 50′ north latitude, deserves the honour of bearing the name of one of those great men England has good reason to be proud of; but what would Vancouver think of his countrymen, if he could look now upon the natural charms of this island, still breathing in her undiminished beauty, but no happy Christian population contentedly smiling through her rich valleys, drawn there not only to enjoy and partake of the bountiful goodness of Providence, but to promote the true welfare and conversion of the poor savages that are thinly scattered over the face of this smiling country, on which the hand of human industry has not yet been laid? Here is a soil the richest I know of, without a human being to draw from it even the minimum of human exertion, a soil that will produce whatever the husbandman may design to cultivate; the aboriginal inhabitants neither plant nor sow, but live upon the spontaneous products of the soil,—a few roots. Do we not claim this island as a part of our possessions? and does not this ownership hold us in duty to promote to the utmost of our ability the amelioration of the moral and civil condition of these savage or semi-barbarous Indians, for the purpose of gradually fitting them to assume the characters and station of freemen,—to emancipate these poor creatures from their degraded position by civilization? I am sorry to see projects entered into with regard to the colonization of this island, that reason and policy, upon a closer investigation, and humanity itself, would pronounce to be premature. This island, under the existing state of affairs, is not likely to receive many colonists; all those who are intending to emigrate will be scrupulous in purchasing land. I consider the grant of Vancouver Island to the Hudson's Bay Company as an unwise act. The evil consequences attending the Company's exclusive right to the fur trade will be soon felt by every colonist.

But notwithstanding we make false moves in our colonies, we may be justly proud of them all, whether they be connected with or independent of the parent state; and may feel not a little vain, that the benefits we have conferred on our species, equal, ay, surpass, what has been accomplished by the whole of the other nations of Europe put together. The present system, with regard to the sale of lands in a new colony (especially Vancouver), appears to me to be founded on a false principle. Every fraction produced by the sale of lands in a new colony, should go to the ameliorating the condition of the aboriginal inhabitants; if you want a stimulus to immigration to a particular colony, let not that stimulus be given at the expense of the poor savage,

whose country you have taken possession of; but rather let the land be sold at a cheaper rate than it generally is, and the money placed as a fund to improve the moral and domestic condition of the savage, and not for immigration. What is required for Vancouver is for the Government to encourage emigration by facilitating the means of transport: and as first impressions are strongest, let there be imported into Vancouver, colonists possessing the sterling qualities of our British labourer,—fidelity, hardy and industrious habits, and strong domestic affections.

There are strong reasons for assuming that this will turn out a fine mining country; they have already found, and are working successfully, plenty of superior coals, which will become the nucleus of every nation's wealth.

On an Inscription in the Language of Ancient Gaul, and on the recent researches of Zeuss *and others into that Language. By* R. Siegfried, *Ph.D.*

On the present Condition of the Natives of Australia, in a Letter to R. Cull, F.S.A. By the Rev. J. Threlkeld.

On the supposed unity of the American Race. By D. Wilson, *LL.D.*

STATISTICS.

Introductory Address by the Archbishop of Dublin, *President of the Section.*

In opening the business of this Section there is no occasion for me to enter into any lengthened detail of its characteristic objects, for these, I presume, must be sufficiently known to most of you. Our department is conversant about almost all the most important transactions of human life, as far, at least, as this present world is concerned. It is conversant about all that relates to prosperity, national and individual,—all that relates to the promotion of honest industry and fair dealing between man and man,—all that relates to the repression of crime,—all that relates to the spreading of industrious, sober and useful habits,—all that relates to the mitigation or prevention of famine and pestilence,—all these come within our department; and if there be any one thing which it is needful that all should have some knowledge of, it must be that which all persons are concerned about,—which all persons must do and attend to, and which it is highly important that they should be instructed how to do well. We collect, and reason from, facts relating to all these matters. We do not encroach on the department of any branch of science, but we lend our aid to almost all,—there is hardly any one which, in its practical results, is not more or less connected with ours. For example, the procuring of valuable substances from peat, which you must have all heard of,—that is a matter for the chemist; the cultivation of beet for the production of sugar is a matter for the chemist and the agriculturist; but how far these processes can be made profitable and valuable, that is, how far they will be worth attending to, is a question that comes within our department. Again, there is the important invention of the manufacture of soda from sea-salt. That is a matter, of course, for the chemist. We, in our economic department, have nothing to do with that; but with the commercial results, and, I may add, the practical and moral results of it, we are greatly concerned. The increased cheapness of soda, which has been the result of that invention, has created a very greatly increased demand for soap, through its increased cheapness; and that has created an increased demand for the supply of the oils necessary for the manufacture of soap. That, again, has occasioned a very great demand for palm oil from Africa, which has contributed to check, more than probably any other cause, the progress of the slave trade; because the barbarian African chiefs find that it answers better and is more

profitable to employ their people in extracting palm oil than in kidnapping and selling them for slaves. I mention these few, and might mention fifty other instances, in which the results of other branches of science come under our department, and are to be considered with a great deal of care and attention, in order that we may arrive at correct results. Some people have, or had, at least some years ago, a sort of dread that attention to these subjects would lead us to be too worldly and too attentive to gain; not considering that our pursuit has no more necessary connexion with the acquisition of wealth, than it has with charity. Charity everybody allows to be a virtue; but there is hardly any vice that produces so much mischief as misdirected charity; and how charity may be so directed, and distress so relieved or prevented, as to occasion the greatest good and the least evil, is a matter that comes within our department. This world is the place in which we are fixed, and in which our duties are to be performed; and it is absolutely necessary, if we would perform our duties aright, that we should know the circumstances under which those duties are to be performed. A person is not excused from merely meaning well if he neglects to acquaint himself with all the circumstances which will enable him to carry his good intentions into effect; and therefore it is, that, although I have said our department is conversant in matters pertaining to this world, yet this world is connected with the next, as it is the same God that is the author of both worlds; and it is most essential that we should be acquainted with the circumstances that regulate human transactions wherein our duties lie. On these subjects I hope some very interesting and important communications will be made on this and on succeeding days.

On the Car Establishment of Mr. Bianconi *in Ireland. By* C. Bianconi.

Referring to the synopsis of my establishment, submitted in a concise form to the Association at its Session in Cork, in 1843, I now take the liberty of submitting some further particulars, embracing its origin, with its present condition, and the extent of its operations.

My establishment originated immediately after the peace of 1815, having then had the advantage of a supply of first-class horses intended for the army, and rating in price from ten to twenty pounds each, one of which drew a car and six persons with ease seven miles an hour. The demand for such horses having ceased, the breeding of them naturally diminished, and, after some time, I found it necessary to put two inferior horses to do the work of one. Finding I thus had extra horse power, I increased the size of the car, which held six passengers—three on each side—to one capable of carrying eight; and in proportion as the breed of horses improved, I continued to increase the size of the cars for summer work, and to add to the number of horses in winter for the conveyance of the same number of passengers, until I converted the two-wheeled two-horse cars into four-wheeled cars, drawn by two, three or four horses, according to the traffic on the respective roads and the wants of the public. This freedom of communication has greatly added to the elevation of the lower classes; for, in proportion as they found that travelling by car, with a saving of time, was cheaper than walking with a loss of it, they began to appreciate the value of speedy communication, and hence have been, to an almost incalculable extent, travellers by my cars, where, mixing with the better orders of society, their own moral elevation has been of a decided character.

As the establishment extended, I was surprised and delighted at its commercial and moral importance; I found, as soon as I had opened communication with the interior, the consumption of manufactured goods had greatly increased. The competition of parties availing themselves of the facilities of travelling was so great, that instead of buying at second-hand, after many profits, they were enabled to obtain the supplies nearer the manufacturer—in the more remote parts of Ireland. For instance, on my opening the communication from Tralee to Cahirciveen in the south, Galway to Clifden in the west, and Ballina to Belmullet in the north-west, purchasers were obliged to give eight pence or nine pence a yard for calico for shirts subsequently sold for three pence and four pence, thus enabling that portion of the population who could previously badly afford only one shirt each to have two for a less price than was paid for one, and in the same ratio other commodities came into general use at reduced prices.

The formation of my first car, conveying passengers back to back, on the principle of the outside car, now so much used in Dublin, was admirably adapted to its purposes, and it frequently happened that, whilst on one side were sitting some of the higher classes, persons as opposite in position were seated on the other. Not only was this unaccompanied with any inconvenience, but I consider its effects were very salutary; as many who had no status were, by coming into casual communication with the educated classes, inspired with the importance of, and respect for, social position.

The growth and extent of railways necessarily affected my establishment, and diminished its operation, by withdrawing from it ten two-wheeled cars, travelling daily 450 miles; twenty-two four-wheeled cars, travelling daily 1620 miles; five coaches, travelling daily 376 miles; thus making a total falling off of thirty-seven vehicles, travelling daily 2452 miles. Notwithstanding this falling off, the consequent result of the extension of railways, I still have over 900 horses, working thirty-five two-wheeled cars, travelling daily 1752 miles; twenty-two four-wheeled cars, travelling daily 1500 miles; ten coaches, travelling daily 992 miles; making in the whole sixty-seven conveyances, travelling daily 4244 miles, and extending over portions of twenty-two counties, viz. Cork, Clare, Carlow, Cavan, Donegal, Fermanagh, Galway, King's, Kilkenny, Kerry, Limerick, Longford, Leitrim, Mayo, Queen's, Roscommon, Sligo, Tipperary, Tyrone, Waterford, Wexford and Westmeath.

Anxious to aid as well as I could the resources of the country, many of which lay so long unproductive, I used this establishment, as far as practicable, to effect so desirable an object. For instance, I enabled fishermen on the western coast to avail themselves of a rapid transit for their fresh fish, which, being a very perishable article, would be comparatively profitless unless its conveyance to Dublin and other suitable markets could be ensured within a given time, so that those engaged in the fisheries at Clifden, Westport, and other places, sending their produce by my conveyances in one day, could rely on its reaching its destination the following morning, additional horses and special conveyances being provided and put on in the proper seasons. The amount realized by this valuable traffic is almost incredible, and has, in my opinion, largely contributed to the comfort and independence now so happily contrasting with the lamentable condition which the west of Ireland presented a few years since.

I shall conclude by two observations, which, I think, illustrate the increasing prosperity of the country and the progress of the people. First, although the population has so considerably decreased by emigration and other causes, the proportion of travellers by my conveyances is greater, thus demonstrating that the people appreciate not only the money-value of time, but also the advantages of an establishment designed and worked for their particular use and development, now forty-two years in operation. Secondly, the peaceable and high moral bearing of the Irish people, which can only be known and duly appreciated by those who live amongst them, and who have, as I have had, long and constant intercourse with them. I have therefore been equally surprised and pained to observe in portions of the respectable press, both in England and Ireland, repeated attacks on the morality of our population, charging them with a proneness to violate the laws and with a disregard of private property; but as one fact is worth a thousand assertions, I offer, in contradiction of those statements, this indisputable fact:—My conveyances, many of them carrying very important mails, have been travelling during all hours of the day and night, often in lonely and unfrequented places; and during the long period of forty-two years that my establishment has been in existence, the slightest injury has never been done by the people to my property, or that entrusted to my care; and this fact gives me greater pleasure than any pride I might feel in reflecting upon the other rewards of my life's labour.

On the Proportion of Marriages at different Ages of the Sexes.
By S. Browne.

On some of the Principal Effects of the New Gold, as an Instrument of Purchase, on the Production and Distribution of Real Wealth. By Professor Cairnes.

The expression "as an instrument of purchase," was used in order to exclude the consideration of the indirect effects of the gold discoveries on real wealth, through

the influence which they would exercise on the dispersion of mankind, and the question was thus narrowed to the effects of the new gold, in its capacity as a portion of the general circulating medium of commercial nations.

Viewed in this light, it was contended that the new gold had no direct tendency to stimulate industry or increase real wealth (understanding by this latter term commodities which contribute to human enjoyment as distinguished from "money," or the instrument for exchanging such commodities). The gold discoveries had not added to the fertility of natural agents, nor to the intelligence of capitalists, nor to the health or strength of labourers; nor, therefore, except so far as gold was desired on its own account (that is to say, so far as it was *not* used as money), to the motives to exertion of the human race. A given sacrifice would now produce more gold than formerly, but not more of any other thing. So far, therefore, as "other things" were the inducement to exertion, the new gold could not stimulate industry or increase real wealth; unless it did so in one or other of the following ways;—viz. first, by practising some illusion on the understanding, so as to induce men to undergo a greater sacrifice for a given reward than formerly; or secondly, by causing such a change in the distribution of wealth, as might, at the expense of the idle or less actively producing classes and nations, operate as a premium on its production.

In both these ways it was contended that the new gold would lead to an augmentation of the real wealth of society.

With regard to the first, it was shown, that after gold through the increase in its quantity had become depreciated in value, the recognition of the change in its whole extent would not be immediate. £100 would cease to represent the same quantity of commodities as before, but its influence upon the mind as a stimulus to exertion would not at once decline in the same proportion. Those who gained by the monetary revolution would appear to gain more, and those who lost would appear to lose less; and both, measuring their reward rather by its nominal than by its real standard, would, for a time and until the rise in prices had been very decidedly established, be, as it were, cheated into increased exertions. All would more or less feel the influence of the new gold in this respect, but those who would be most infinitely affected by it would be those in the determination of whose remuneration competition was modified by custom—such as the recipients of fixed salaries, fees, &c.

But secondly, the new gold tended to augment real wealth through its effects on distribution.

The effect of the new gold was not, according to the popular idea, to increase the demand for commodities in general, but to cause a redistribution of purchasing power, and thus to cause a disturbance in the demand for commodities. It was the same in effect as if a tax were levied over the world, and the proceeds deposited in the sands of Australia and California. Those who gained by the new monetary changes did not gain simply because their money incomes were increased, but because they were raised *relatively* to those of others: they could therefore appropriate a larger share of the general wealth; and, for the contrary reason, those whose money incomes were not similarly affected, could appropriate a smaller share than before. The gain depended on the rise in money income as compared with the rise in the price of the articles on which it was expended. It followed therefore, that, for a given amount of gold, those who gained most were the original finders, and, the earlier it was found, the greater the gain.

Applying these principles to the case in hand, the gold-finders were the greatest gainers, the merchants and manufacturers who were best able to supply their most pressing needs were gainers in the next degree, and afterwards those who could supply the wants of such merchants and manufacturers; or, turning from classes to nations, the gold countries were the greatest gainers by the new gold; the United States and England the next; while the countries who would suffer most by the new movement would be such countries as India and China, who would not receive their share till it had first operated on prices in most of the markets of the world. England during the Russian war could, in consequence of the gold discoveries, command with a given outlay of labour and capital a greater amount of gold than before. With this gold she came into the markets of Turkey, which had not yet felt the effects of the Australian discoveries, and carried off an increased amount of such things as she required, to the injury, of course, of all her competitors in the same market. The pressure of the war-strain was thus lightened in proportion to her cheapened cost of obtaining gold.

In further illustration of the same principle, the trade of England and America with India and China in recent years was referred to. During the last seven years, not less than sixty millions sterling in gold and silver had been sent to the East in payment of increased imports from oriental countries. This was, in other words, to say that real wealth to that amount had, during that time, been obtained from these countries for which, not "real wealth," but money had been returned. It was evident, therefore, that unless India and China had worked very much harder during that period, they must in real wealth be very much poorer. The new gold thus tended to enrich England and America and the gold countries at the expense of India and China and countries similarly situated.

Such being the effect of the new gold on the distribution of real wealth, it was not difficult to see that the effect of the change would be indirectly to stimulate its production. In every instance the transfer was in favour of the more active of the producing classes and nations at the expense of the idle or less active, and, in general, in favour of the Anglo-Saxon race at the expense of the rest of the world. The effect would be the same as if a tax were laid on the idle for the benefit of the industrious.

The character of the new movement being determined by these principles, the magnitude of the consequences resulting would depend on two conditions:—first, on the permanent diminution which should be effected in the cost of producing gold; and secondly, on the slowness with which this diminution in cost would be neutralized in the general rise of prices which would result.

From the rise which had been established in money-wages in the gold countries, it was deduced that the cost of obtaining gold had in these countries been diminished by one half. Prices, therefore, in these countries would rise in general to double their former range, and the laws of international exchange would tend to bring about a corresponding advance in all other countries.

The rate at which the advance took place would depend, not simply on the actual quantity of gold annually produced, nor yet on the relation of the new increments to the quantity previously in existence, but also on the extensions which the trade of the world would in the mean time undergo; and, considering the great increase of productive power lately brought into operation, as exemplified in the extension of railways, the development of free trade, the improvements in ship building, the electric telegraph, and the increased application of scientific inventions to productive processes—there was every reason to expect that such extensions of commerce would be considerable, and that thus the rise in prices would not be so rapid as, looking simply to the increased production of gold, we might be led to expect.

From these principles it followed that in all future extensions of trade England and America (including under these names the gold countries—their colonies) would have a double interest:—first, from the advantage which, in common with all commercial nations, they would derive from a more efficient application of the productive forces of the world; and secondly, from the special benefits which, as gold-producing countries, they would enjoy through retarding influence which such extensions of trade would exert on the general range of prices throughout the world; thereby enabling them to avail themselves, to a greater extent and for a longer time, of their cheapened cost of gold.

On the Dependence of Moral and Criminal on Physical Conditions of Populations. By E. CHADWICK.

On the Economical, Educational, and Social Importance of open and public Competitive Examinations. By E. CHADWICK.

On the Effect of Good and Bad Times on Committals to Prison. By H. CLAY.

On the Ages of the Population in Liverpool and Manchester. By J. T. DANSON, *Barrister-at-Law.*

Mr. Danson laid before the Section some tabular statements, drawn from the last

Census, in which, assuming that the proportion of the active, ruling, and productive portion of the population would be found nearly represented by the number of males from 25 to 55 years of age, it was shown that this proportion was considerably higher in the north-western division of the kingdom than in the rest of it; higher in Manchester (including Salford) than in the north-western division; and considerably higher in Liverpool than in Manchester. Details were also given showing the relative proportions in each case of the female, and of the immature and aged male population, making up, in each case, the remnant of the population. And from the materials thus stated were deduced the general conclusions,—

That as not only the *productive and defensive power*, but also *the character and conduct* of a given population is dependent, in a great measure, upon the ages of the individuals composing it, so sanitary improvements, by lengthening the duration of life, tend directly to increase the proportion of mature and aged persons to the whole of the population on which they take effect, thus prolonging the effects of experience upon such a population; and when taken with the prestige commonly conferred upon opinions by the ages of those who utter them, may be expected to give a corresponding influence to reason, as opposed to passion, in the affairs of a population so placed.

That the high and increasing value of life in England indicates a large and increasing proportion of matured minds; and undoubtedly has a corresponding influence on the exercise of the national will, as well at home as abroad—an influence already traceable in our political history; and that there is no apparent reason why municipal action should not be influenced by the same causes.

TABLE I.

Ages in the Larger Areas.

1851.	England and Wales.		North-Western Division.		To 10,000 Males aged 25—55.			
					England and Wales.		North-Western Division.	
	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.
Total Popultn.	8,781,225	9,146,384	1,215,832	1,274,995	28,668	29,860	27,629	28,973
0—25..	4,859,667	4,917,952	684,452	705,784	15,865	16,055	15,554	16,038
25—55..	3,063,111	3,248,458	440,058	464,953	10,000	10,605	10,000	10,566
55 and upwards	858,447	979,974	91,322	104,258	2,803	3,199	2,075	2,369
0— 5	1,176,753	1,171,354	165,671	165,827	3,842	3,824	3,765	3,768
5— 10	1,050,228	1,042,131	142,747	142,655	3,429	3,402	3,244	3,242
10— 15	963,995	949,362	134,111	133,628	3,147	3,099	3,048	3,037
15— 20	873,236	883,953	124,128	130,230	2,851	2,886	2,821	2,959
20— 25	795,455	871,152	117,795	133,444	2,597	2,844	2,677	3,032
25— 30	699,345	771,130	105,244	116,350	2,283	2,517	2,392	2,644
30— 35	617,889	658,237	91,082	97,547	2,017	2,149	2,070	2,217
35— 40	532,680	555,879	76,227	78,909	1,739	1,815	1,732	1,793
40— 45	474,211	494,408	68,653	71,023	1,548	1,614	1,560	1,614
45— 50	392,882	406,107	53,709	55,135	1,283	1,326	1,220	1,253
50— 55	346,104	362,697	45,143	45,989	1,130	1,184	1,026	1,045
55— 60	254,892	271,395	29,482	31,807	832	886	670	723
60— 65	227,240	254,070	25,406	28,856	742	829	577	656
65— 70	151,640	175,879	15,903	18,732	495	574	361	426
70— 75	114,730	135,432	11,362	13,140	375	442	258	299
75— 80	65,016	81,086	5,741	7,082	212	265	130	161
80— 85	31,690	42,150	2,461	3,275	103	138	56	74
85— 90	10,423	14,982	772	1,031	34	49	18	23
90— 95	2,282	3,969	151	268	7	13	3	6
95—100	456	874	37	54	1	3	1	1
100 and upwards	78	137	7	13	..	..	..	..

TABLE II.

Ages in Manchester and Liverpool.

1851.	Manchester City and Salford Borough.		Liverpool Borough.		To 10,000 Males aged 25—55. Manchester and Salford.		To 10,000 Males aged 25—55. Liverpool.	
	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.
Total Popultn.	191,457	209,864	182,058	193,897	26,054	28,558	24,707	26,313
0—25..	106,518	113,002	98,559	103,630	14,495	15,377	13,375	14,063
25—55..	73,488	82,092	73,688	77,259	10,000	11,171	10,000	10,485
55 and upwards	11,451	14,770	9,811	13,008	1,558	2,010	1,331	1,765
0— 5	25,705	26,031	23,976	23,938	3,498	3,542	3,254	3,249
5— 10	21,478	21,318	20,498	20,118	2,923	2,901	2,782	2,730
10— 15	19,974	20,419	18,950	18,701	2,718	2,783	2,572	2,538
15— 20	19,394	21,245	17,226	18,781	2,639	2,891	2,338	2,549
20— 25	19,967	23,959	17,909	22,092	2,717	3,260	2,430	2,998
25— 30	17,952	20,641	17,137	19,356	2,443	2,809	2,326	2,627
30— 35	15,269	17,452	16,373	17,312	2,078	2,375	2,222	2,349
35— 40	12,573	13,818	13,024	13,501	1,711	1,880	1,767	1,832
40— 45	11,755	12,787	12,105	11,893	1,600	1,740	1,643	1,614
45— 50	8,692	9,460	8,118	8,135	1,183	1,287	1,102	1,104
50— 55	7,247	7,934	6,931	7,062	986	1,080	941	958
55— 60	4,089	4,727	3,569	4,019	557	643	484	545
60— 65	3,403	4,349	3,012	3,957	463	592	409	537
65— 70	1,822	2,478	1,509	2,179	248	337	205	296
70— 75	1,239	1,801	1,021	1,544	169	245	139	210
75— 80	560	862	455	775	76	117	62	105
80— 85	236	403	164	380	32	55	22	52
85— 90	79	113	64	100	11	15	9	14
90— 95	15	23	12	38	2	3	2	5
95—100	5	12	4	10	1	2	1	1
100 and upwards	3	2	1	6	..	..	..	1

On the Effects of the Gold of Australia and California. By J. CRAWFURD.

The principal results sought to be established were, that the enormous quantities of gold and silver suddenly thrown upon the market during the last nine years have not produced a proportionate depreciation in the price of these metals, and rise in prices; and that the cause of this arises from the capacity of modern industry to increase indefinitely the impetus given to manufactures and commerce by the discovery of the precious metals.

The experience of the last nine years leads to the conclusion that the great fall in prices commonly supposed to have taken place in the sixteenth and seventeenth centuries, after the discovery of the American mines, if it really took place, did not arise from this cause, but from the growth of industry thus fostered, and the general progress of society. The author pointed out that, unless new mines are discovered, the proportion of gold and silver yearly imported to the old stock will be diminishing gradually, and that in any case the industrial development will absorb the new supplies.

A Cash Land-Trade for Ireland, Retail and Wholesale.
By RICHARD DOWDEN.

The difficulties which embarrass dealings in land at present were detailed; and these embarrassments were stated to have been the principal provocatives of all the agrarian mischiefs and sorrows which have troubled Ireland for many years.

"*The land*" is the elementary basis of all civilized industry; and the desire to possess this kind of capital is so universal, as almost to influence mankind everywhere like an instinct.

The reasonable gratification of this urgent desire demands a more easy commerce in land than we have as yet attained to.

The facilities given by "The Encumbered Estates" sales have led the way in this good change; and the extension of that law to properties not encumbered, indicates courage in the progress towards a real free-trade in land which is greatly encouraging and hope-inspiring. If land could be bought and sold in lots of all suitable sizes, several vague inventions proposed for giving either a factitious, or an arbitrary possession of the soil, would be rendered unnecessary. "Tenant-right," as yet an unread riddle, would be left in its impracticability, and real possessions made by cash purchases would be a solid, and not a visionary landownership.

The excessive emigration of our people has been induced because our agricultural population cannot buy small lots of land at home; the result is, that savings gathered with much denial at home, are invested in small purchases of "real estate" in Canada and elsewhere abroad. We want a yeoman class of contented settlers in Ireland, and might soon have them if land were sold in small parcels without difficulty, and only for cash.

The writer suggests the construction of a "land-market" for *retail-land* sales, one in each of Ireland's four provinces; and that the facilities of these marts be only afforded to cash purchasers: he thinks land should be sold in parcels of from one acre upward, as is now done in Canada.

The author also recommends that "all superior rights, even royalties, should be sold to purchasers," so as to make owners real *freeholders*; believing that without an easily acquired and perfect ownership in the soil, the powers of the people, and the capabilities of the land, cannot be properly or fully developed.

On the Necessity of Prompt Measures for the Suppression of Intemperance and Drunkenness. By JAMES HAUGHTON.

The drinking usages of society cast greater impediments in the way of national improvement than any other cause which could be named.

That education alone is insufficient to effect the overthrow of intemperance, Dr. Lees' statistics of 24 counties in England, prove that 12 of these counties, in which large means of education exist, have more crime than the other 12 in which there are fewer such facilities. Drinking customs explain the difference. In the first 12 counties there are 147 public houses, and the crime is 119. In the second, the numbers stand, 58 public houses, 78 crime. In making these calculations a mean is taken for all the counties in England, and the relative population is taken into account. So much for the insufficiency of education.

Drinking accumulates from generation to generation. The consumption of whisky in Ireland during the last century proves this. It increased 90-fold, while the population increased but 4-fold.

Number of visits to public houses in Edinburgh, on a single Sunday:—men, 22,202; women, 11,931; children, 7663: and to taverns, 6609. In Manchester,—men, 120,122; women, 71,111; children, 23,585.

The use of the poison alcohol by persons in health is condemned by the first authorities; not a single one of eminence is found in its favour.

Number of dealers in intoxicating liquors in 1854, in the United Kingdom, 163,985. Supposing these to receive not more on an average than £3 per day each, which, allowing them a profit of 25 per cent., would hardly keep their establishments open, the annual sum we spend on the poison alcohol is £179,563,575,—a fearful waste of national resources.

'The Times' tells us of the physical deterioration of the French people, which is thus easily accounted for. They consume about 1,054,000,000 gallons of strong drinks annually, which is equal to $4\frac{1}{2}$ gallons ardent spirits per head of the population; England being about $3\frac{1}{4}$; Scotland 3; Ireland $1\frac{1}{4}$; Prussia $1\frac{1}{10}$; the United States $1\frac{5}{8}$.

Distillation only pays in labour about 11 per cent. on first cost of raw materials; cabinet-making 60 per cent.; coach-lace making 50; silk fabrics 20; curled hair 25.

Prohibitory legislation is in accordance with the usual course of legislation, but neither sought for, nor desirable, until sustained by public opinion. Enlightening public opinion by calm discussion is therefore the great means we employ for attainment of the end in view.

On Agricultural and Manufacturing Industry. By JOHN POPE HENNESSY, *Inner Temple.*

Having contrasted the views of Adam Smith and those of the modern school of British economists, with reference to the relative importance of agriculture and manufactures, the author proceeded to examine the principles on which the modern economists rely. Regarding Mr. Senior as a fair and accurate exponent of the modern school, he made his treatise on 'Political Economy' the groundwork of the memoir.

Taking what Mr. Senior calls the fourth elementary proposition, the author stated it in a threefold form :—"(1) Skill and space remaining unaltered; (2) additional labour employed on land occasions an increase in the produce, (3) but an increase in a diminishing ratio." The five fundamental terms used in treating the agricultural side of the question are,—skill, labour, space, produce, and materials. In treating the manufacturing side of the question, however, he showed that the modern economists neglected one of these terms, and used another of them with a different signification. He traced at great length the effect of this omission, and pointed out the anomalous results to which it has given rise. Applying a general principle, similar to the fourth elementary proposition, to both sides of the question, he established the following conclusions; viz.—1st. that skill and space remaining the same, additional labour is more efficiently employed in agriculture than in manufactures; and 2nd, that skill remaining the same, additional labour and capital are more efficiently employed in agriculture than in manufactures.

Having disposed of the theoretical part of the question, the author proceeded to examine the practical facts which bear upon it. He quoted largely from the statistics of the growth and prices of cotton in America, and the statistics of the production of corn in Prussia and in Great Britain. From the statistical tables he exhibited, it appeared that practical experience completely confirmed the views of Adam Smith, and was altogether at variance with the opinions of the modern school. The final result of the memoir consisted of an application of the principles it attempted to establish to the laws regulating the incidence of taxation.

On the Prevention of Crime. By WILLIAM H. JEMISON, *LL.B., Dublin.*

The proper object of criminal jurisprudence is the prevention of actions that are injurious to person or property. Such actions arise from one, or all, of three sources: the smallness of the offender's means; the weakness of his moral principle; or the strength of the inducement. Hence, in order to prevent their occurrence, we must better the material condition of the lower classes, improve their moral principles, and diminish the inducement to crime by the intervention of punishment. The material condition of the lower classes is promoted by diffusing intelligence and prudence; by the duties of the wealthy and educated being properly performed; by useful public institutions; and by freedom for industry and security for its fruits. Secondly. Crimes that arise from deficiency of moral principle, will decrease with the spread of religion and morality. Lastly. Effective punishment must partake of three characteristics: its nature, and the liability to it, must be properly made known; its connexion with the offence must be felt as certain; and its severity must be such as to outweigh the advantage expected from crime. The first-named characteristic is inconsistent with magisterial discretion as to the punishments awarded; with their infliction being in any measure conditional on the after-conduct of prisoners; and with commuting sentences. Secondly. The certainty of connexion between an offence and its penal consequences must be attained by securing the detection, conviction, and real punishment of offenders. Detection is promoted by improvements in our police system; and conviction by reforms in our criminal law and its administration.

These reforms will involve a better organization of our legal service, a revision of our rules of evidence and trial, and the removal of useless technicalities. Thirdly. As we approach certainty in the matters of detection and conviction, the less need be the severity of our penal code. This suggests a moral consideration. That amount of severity is not justifiable which is a set-off against imperfections which we can remove from our penal legislation.

In the Reformatory movement of the present day, the great object of criminal law is overlooked. Lord Brougham, *e.g.*, one of the supporters of the movement, lays down the proposition, "that all punishment should be conducted mainly with a view to reforming the offender*." From the laws of our moral nature, however, the practicability of this system must be very doubtful. But its grand error is, that it mistakes its proper object. The inculcation of moral lessons to reform convicts, and the infliction of such punishment as will deter others from committing offences, are objects so widely apart, that they must be reached by far different roads; and the latter object, and not the former, is the end of criminal law.

The Juvenile Reformatories, also, are open to grave objections. Their position is unnatural, for they seek to discharge parental duties. Their effects too are mischievous, for instead of public attention being directed to such means as will assist parents in rearing their children, these institutions tend to impress them with the notion that they shall be relieved, if not from supporting, at least from caring for their offspring.

We must, indeed, deprecate immoral tendencies in the arrangements of our gaols; but the prevention of crime is to be promoted, not by reforming convicts, but by improving, materially and morally, the mass of the people, and by the detection, conviction, and punishment of offenders.

On the Progress of Free Trade on the Continent. By M. JOTTRAND, *of Brussels.*

Sketch of the Rise, Progress, and Present Prospects of Popular Education in Ireland. By J. W. KAVANAGH, *Head Inspector of National Schools.*

On Competition at the Bar. By Professor LESLIE.

On Professional Incomes. By Professor LESLIE.

The Land-Revolution in Ireland. By JOHN LOCKE.

This paper, on the subject of "The Encumbered Estates Commission," was communicated, on a day's notice, at the request of several Vice-Presidents of the Statistical Section, and therefore some of the figures could only be considered as proximatively correct; but the results, which the author had anticipatively sketched at the Belfast meeting in 1852, and again at Hull in 1853, had been fully verified by the subsequent success of this remarkable tribunal.

Number of petitions presented up to this date, 4159; number of conveyances executed, 7105; total produce of sales, twenty millions and seven-eighths, of which about two-thirds, or fourteen millions†, had been distributed. About two million acres, or nearly a seventh of the available superficies of the island, had fallen under the hammer of the court; and over that extent the proprietors were increased in number about eight and a half-fold. The expenditure on improvements of these new and solvent landlords constituted the principal cause of the rise in the wages of labour, which were doubled since the date of the establishment of the Commission. During the eight years of its continuance, from three to four millions yearly were poured into reproductive channels over the surface of this impoverished agricultural country, *i. e.* taking into account the capital laid out on the land by purchasers, as well as the

* National Reformatory Union; Authorized Report of Bristol Meeting, 1856, p. 58.

† Cash only.—Investments in Government Stock, and credits to encumbrancers who purchased, may amount to four millions more.

millions set free, that had been locked up in barren mortgages for scores of years. Up to the end of the legal session of 1853, the British purchasers were, as to number, one in twenty-three; as to total amount of purchase-money, one-sixth. Since that date, both these proportions had fallen off, and the Irish had now their land market almost entirely to themselves. However, the fee of upwards of 600,000 acres in Connaught, or nearly one-sixth of its extent, had been acquired by British purchasers; and the intermixture of these, and of English and Scotch farmers settled in the far West, with the native proprietors and their tenantry, tended greatly to improve and develope the resources of this, the most neglected province in Ireland. The facilities afforded for sale and transfer, and the vast extent of land thrown into the tenant-market by the agency of the Commission, has certainly prevented tenant-right agitation from assuming a dangerous agrarian aspect.

In allusion to the ruinous condition of landed property in the famine years, the author had been examined before the Committee of Peers on the subject of the labour-rate debt, and stated, from his personal knowledge, that long before the evidence was closed, the British Peers on the Committee had resolved unanimously to recommend a remission of the debt. They merited our gratitude; for had it been enforced, a vastly greater number of our landlords would have been ruined, by their estates being forced into a depreciated market during the panic that succeeded the famine.

Registration of title by map was strongly urged on the consideration of the Section, as a necessary complement to the completeness of a great land-sale tribunal; and the author quoted, in support of that proposition, a portion of his own evidence before the "Registration of Title Commission." A map, correctly executed, under careful supervision, spoke a more clear and definite language than even the wording of the abstract. The Ordnance Survey was available as an auxiliary, and the instrumentality might be applied, through means of the machinery of the Encumbered Estates Court itself, at a small additional cost. Had this plan been adopted, the titles to nearly one-seventh of the country would now have been in a forward process of registration by map.

The Encumbered Estates Act had effected the most extensive and salutary revolution which had ever occurred in Ireland, and that too without exciting one angry international feeling. But its beneficial results were mainly extrinsic of the condition as to property being encumbered; and the principles upon which it was constituted ought not to be exceptionally applied. In short, both at home and in our dependencies, the liberation of real property from unnecessary legal delays and restrictions, combined with the facility of its sale and transfer, would increase, beyond calculation, both the security and prosperity of the British empire.

The author stated, in conclusion, that the progressive improvements in the sales were in great part attributable to the prudence and cleverness of the conducting solicitors; but that the success of the Commission itself was due to the zeal and ability of the Commissioners, especially the late Chief-Commissioner, Baron Richards, with whose name were indissolubly connected the benefits conferred upon Ireland by a tribunal which that learned judge so efficiently organized and so indefatigably worked in its earlier stage of difficulties and unpopularity.

On the Influence of inadequate or perverted Development in the production of Insanity, Disease, Want and Crime. By Dr. H. M'Cormac.

On the Progress of Free Trade on the Continent. By M. Corr Vander Maeren.

Registration of Births, Deaths and Marriages in Ireland. By Arthur Moore, *M.B.A.*

After some preliminary observations as to the uses and importance of a general registration of births, deaths and marriages, the author described the systems in use in England and Scotland, and their results; and adverted to the anomaly of Ireland being the only part of the United Kingdom, and almost the only country in Europe, without such a registration. He observed that the object of his paper was not so

much to dwell on the value of the registration or on the above anomaly, as to invite attention to the subject and discussion of it, with a view to consider the means of supplying the want and to show the practicability of doing so.

In Ireland there is no registration whatever of births and deaths, and but a very limited registration of marriages under the Irish Marriage Registration Act of 1844, which however does not include the bulk of the population, the Roman Catholics.

The author proposes to remove this exclusion of Roman Catholics from the advantage of registration, by including their marriages in a general and uniform registration corresponding with that of all other of Her Majesty's subjects in the United Kingdom; and he contends that this may be done without offending any religious convictions of any class of the community. The Roman Catholics, like others, are already registered in England and Wales and Scotland. The registry of the Roman Catholic marriages would be made by the Roman Catholic clergy by whom the marriages are solemnized, and by whom they would continue to be solemnized as at present: the registry of other than Roman Catholic marriages is already provided for and would not be disturbed.

For the registration of births and deaths in Ireland, the author proposed to make use of the Poor Law organization established throughout the country, and especially the system of dispensary districts and medical officers now spread all over the whole country in connexion with that organization. He exhibited a map showing the distribution and arrangement of the Union districts, which he would adopt for the chief or superintendent registrar's districts, and which would be subdivided by the Guardians into smaller or registrars' districts, for the registration of births and deaths, by a registrar to be appointed for each by the Guardians of the Union district. He dwelt upon the importance of securing the cooperation of the medical profession in this registration, and of obtaining qualified registrars.

The register of books of births, deaths and marriages, as they became filled, would be deposited and open to searches in the office of the superintendent registrar of the Union district; and certified copies of the entries therein would be made every three months for transmission to a general register-office in Dublin, where they would be indexed and open to searches: and means would thus be afforded of access to the registers of all births, deaths and marriages occurring throughout Ireland. An annual summary and report to be made by the Registrar-General and laid before Parliament.

The author's estimate of the expense of establishing the system proposed, amounted to about £31,586, of which £11,887 would be paid out of the public funds, and about £19,699 out of the local rates. These amounts are about one-third of the cost for England, where the total expense is about £92,000 per annum, of which £27,000 is paid out of the funds of the state, and £65,000 out of local rates. The annual cost of the central office for England is £18,000; that for Ireland would be £6900, being only one-third more for the general registration of births, deaths and marriages, than the present cost (nearly £4000) of the central office for the registration of a small portion of marriages only. The estimate for Ireland is at the rate of a farthing and seven-tenths of a farthing per head on the population, for the charge on the public funds of the state; and one farthing and six-tenths of a farthing on the Poor Law valuation for the charge on the local rates. But the author suggests that the whole of these expenses, for an object of so great and general importance, and one of national rather than local concern, might fairly be charged upon the funds of the state. If that were done for Ireland, it would be equally right that it should be done for the other portions of the United Kingdom. He had, however, followed the existing precedents in this respect, both in his calculations and in the draft of a Bill which he prepared and submitted to the Government in the summer of last year (1856), for carrying out in detail the plan of which his paper gave a general outline.

Reasons for extending Limited Liability to Joint-Stock Banks. *By* Joseph J. Murphy.

It was argued in this paper, that could banking companies of limited liability be established anywhere with perfect facility, the country would be covered with banks, and the small towns and rural districts would be enabled to enjoy those advantages of accommodation from banks having their head-quarters on the spot, which at present are confined to great commercial centres.

It was also argued that if banks had limited liability, a large proportion of those who are now depositors would become shareholders; the proportion of share capital to deposits would be increased, and the banks would be sounder and safer.

For the purpose of security, it was urged that directors ought to be under unlimited liability; and that auditors elected by the shareholders should have full powers of investigation.

These suggestions apply to what is properly banking. With respect to the issue of notes, it was proposed, that should Parliament decide on its increase, any party should be permitted to issue notes against bullion and securities; but that companies should not be permitted to issue notes to a greater extent than their paid-up capital.

It was also suggested that the State ought to withdraw its account from the Bank of England and keep its own cash; partly for the purpose of doing the work more cheaply, and partly in order to dispel the false notion that the Bank of England is somehow a department of State.

On the Apprenticeship System in reference to the Freedom of Labour. By ROBERT NAPIER, *of Glasgow.*

On Cottage Gardening and Labourers' Holdings. By M. NIVERE.

On some of the Economical Questions connected with the Effect of the New Gold in diminishing the Difficulties of the last few Years. By W. NEWMARCH, *F.S.S.*

On the Recent Legislation relative to Joint-Stock Companies and Joint-Stock Banks. By W. NEWMARCH, *F.S.S.*

The author began by a historical outline of the subject. Joint-stock companies are unknown to the common law; but the clear necessity of the case enabled many companies to obtain charters of incorporation, for railway and other purposes, from Parliament in some cases, and from the Crown in others.

In 1844 an Act of Parliament was passed for the purpose of regulating the incorporation and working of joint-stock companies, both for banking and for other purposes. This made the granting of charters of incorporation dependent on the discretion of the Board of Trade, and provided a very elaborate administrative system for their regulation. It did not touch the question of limited liability, which, until 1856, could be conferred only by Parliament. The administrative system thus provided did not work satisfactorily; it was too complex, and gave the public a false idea of security, which, in many well-known unhappy cases, proved not to be well-founded.

In 1856 the well-known Joint-Stock Companies' Act was passed. A great mass of complications was got rid of on that occasion, by laying down the principle, unknown to the common law, but necessary at the present time, that incorporation is not a favour but a right; and, consistently with that principle, but unlike the Act of 1844, the administrative machinery it provided for the purpose of registration, publicity, &c., is extremely simple. The Act of 1856 also empowered companies to constitute themselves with the privilege of limited liability. It did not affect banks which remain under the operation of previous acts, nor insurance companies, which, from the nature of their business, are able to protect themselves against the common-law operation of unlimited liability by treating every policy as a separate contract and inserting therein a clause limiting their liability. Thus the question stands at present.

The author thinks the settlement of the general question of limited liability quite satisfactory, owing both to the fairness of the principle and to the simplicity of the machinery; but is inclined to hesitate about its extension to banking companies, in consequence of the important difference between companies which trade on their own moneys, such as railway and manufacturing companies, and those which, like banks, trade in great part on the money of others. It is perhaps reasonable to attach a more stringent responsibility to the latter than to the former. At the same time the author desires to reserve to himself full liberty of considering any new facts as regards the extension of limited liability to banks.

Census of the Province of Canterbury, New Zealand. *By* Henry John Porter.

On the Census of Sydney, New South Wales. *By* Henry John Porter.

On the Money Grants of the British Association. *By* Professor Phillips, *F.R.S.*

On the Rise, Progress, and Value of the Embroidered Muslin Manufacture of Scotland and Ireland. *By* John Strang, *LL.D.*

This branch of manufactures was first commenced in Scotland in 1770, and extended to Ireland in 1780. Few exhibit such a division of labour as that of sewed muslins. The spinning of the yarn for making the cloth—its warping and weaving, and the reeling of the cotton for embroidery; next the designing and drawing the patterns, either on the stone or zinc plate—the block, stereotype or copperplate engraving—the printing of the patterns on the cloth—the despatch of the different pieces of printed cloth to at least 400 or 500 agents in Ireland—the distribution of them throughout the country for embroidery—the return of them to the agents, and their transit back to Glasgow—their examination and preparation for the bleacher—the various operations through which they pass at the bleachfield—their return to the Glasgow warehouse, there to be made up, ironed, folded, ticketed, arranged according to quality and price, placed in fancy-paper boxes, and packed ready to be despatched either to the home or foreign market. The history of an embroidered collar or handkerchief could indeed tell as varied a tale as that of the famous 'Adventures of a Guinea.'

While a large portion of the labour employed in this industry depends on Ireland, the chief seat of the manufacture is in Glasgow; there are thirty-five to forty manufacturing houses in Glasgow; one or two in Paisley; and about a dozen in the north of Ireland.

The gross value of the sewed muslin manufacture of Scotland and Ireland last year amounted to a little above or below a million sterling. There were employed in it 2200 weavers, 450 pattern printers and pressmen, 200 designers and salesmen, and 3680 females occupied within the warehouse doors in the various manipulations of sewing, darning, ironing, making-up, &c.; while in the work of embroidery itself, there might be 200,000 females employed in Ireland and 25,000 in Scotland. The annual amount of these, according to the average rate of weekly wages paid to such parties, is as follows:—

		Per annum.
Weavers, average wages per week	14*s.*	£80,800
Pattern printers	13*s.* 6*d.*	15,795
Designers and salesmen	43*s.* 10*d.*	22,790
Females in warehouses	7*s.* 11½*d.*	76,128
		£195,513
Embroiderers in Ireland		400,000
„ Scotland		80,000
		£675,513

Adding to this the cost of labour in spinning the yarn for the muslin and the cotton for the embroidery, in bleaching the goods, in making the fancy-paper boxes, baskets, &c. in which the finished goods are packed, it will not be too much to assume that the embroidered muslin manufacturer pays for labour a sum little short of £700,000 a year. The truth is, among the many industries of Great Britain, there are few into which labour enters more deeply than the muslin embroidery manufacture, and in which the labouring classes have a deeper interest.

On the Advantages arising from the Improvement of Tidal Rivers as exemplified by the State of the Clyde. *By* John Strang, *LL.D.*

Though the area drained by the river above Glasgow is 736 square miles, and sends

down water in floods to the extent of 33,885 cubic feet per second, it remained in a state of nature till 1768, having only about 2 feet depth of water. By different engineering appliances it has been rendered navigable for vessels drawing 20 feet of water. This has been accomplished, first, by placing jetties on its sides, whereby to contract the stream and cause it to deepen itself by its own flow and scour; this obtained a depth of 8 feet; secondly, by connecting these jetties by half-tide parallel dykes, a depth of 10 feet, and thereafter by raising them to full-tide dykes, a depth of $11\frac{1}{2}$ feet; thirdly, by the combined processes of dredging and steam navigation prior to 1839, which augmented the depth to 15 feet; and, fourthly, by the combined action of the dykes, deepening machines, and steam-boat traffic, an artificial river has been got at this moment of a depth of 18 feet water at neap, and 20 feet at spring tide.

With respect to the harbour of Glasgow, its changes have been equally marked. In 1800, the whole quay was limited to a few hundred yards; now it extends to about two miles and a half, leaving an extent of harbour of upwards of sixty acres. From these causes the number of vessels arriving at the harbour of Glasgow has increased from 11,505, with a tonnage of 696,261, in 1828, to 17,960, with a tonnage of 1,612,681, in 1857. While in 1828, there was not a steamer above 100 tons at the harbour, now such vessels as the 'Persia' of 3600 tons sail down the river. The cost of the vast improvements made from 1770 to July 1856, has been £2,527,199. The revenue collected during the same period has been £1,603,219, the annual revenues being in 1771, £1046; in 1857, £82,797. The debt of the Clyde Trust is about £92,000, consequently a large portion of what may be called real capital has been paid out of revenue.

The following commercial results may be mainly attributed to the improvement of the Clyde navigation. Before these operations were begun, Glasgow had little or no trade, whereas in 1854 the aggregate value of exports from its harbour was £4,905,557. Previous to 1801 her registered ships were *nil*; in 1856 they amounted to 563, with a tonnage of 204,331. Formerly no ships were built on the river; now there are no fewer than thirty large ship-building yards, which in 1853–54 constructed no less than 266 vessels, having an aggregate tonnage of 168,000 tons, which, with the marine engines made during the same period, involved the enormous cost of nearly £5,000,000 sterling. Previous to the commencement of the river improvements, Glasgow had only 24,000 inhabitants; now she can count 420,000, whilst its annual rental, which in 1750 was only a few thousands, was last year £1,319,720. The improvements on the Clyde have given a most decided impulse to the opening up and working of the rich fields of minerals by which Glasgow is surrounded, and which produced in 1855 from coal and iron alone nearly £4,900,000, and gave employment to 233,912 persons, who received for their labour wages to the amount of £1,975,919. So much for Glasgow.

In a national point of view these improvements have proved equally beneficial. In 1796 the Customs duties levied at Glasgow were only £125, whereas last year they amounted to £718,855. In 1781 the revenue of the Glasgow Post-office was only £4341; in 1856, with a penny postage, it reached £64,958. In one word, while the taxes paid into the public treasury through the city of Glasgow before the Clyde improvements commenced were, comparatively speaking, nothing, the various crown revenues collected there last year reached no less a sum than £2,800,000, or about $\frac{1}{25}$th part of the whole revenue of the country.

On Criminal Statistics. By J. C. Symons.

On the Criminal Statistics of this and certain Foreign Countries. By W. M. Tartt, *F.S.S.*

The paper under the above title was a "Report on Criminal Returns," prepared in conformity with a resolution passed by the Committee of Section F at the Meeting of the British Association in 1856.

Its object was to inquire into "the present mode of framing our criminal returns, and the best means of improving them," with especial reference to the forms adopted in France and Prussia. During the sittings of the Committee, its attention had fre-

quently been called to the imperfect character of the materials on which we had long depended for our criminal statistics; but improvements were even then being introduced which have anticipated much that might otherwise have been proposed. The discussions at the meetings of the International Congress, Lord Brougham's speech on Judicial Statistics, and the newly-established statistical department at the Home Office, had already had a practical influence.

As part of the Report, abstracts are given of the Forms of all the returns in use previous to Michaelmas 1856, of those subsequently introduced, and of some of those which have been adopted in France and Prussia. Our own (previous to 1856) had reference to the mere number and nature of the offences and their punishment, rather than to the character and sources of our criminal population; and in some of their details there was a minuteness which had no useful object. The information to be derived from the police did not form any established part of the particulars required. It is suggested that in future the information collected from this and other sources should, in the first instance, be as comprehensive as possible; but that, in giving it an abridged or tabular form, there should be a distinct bearing upon some social or legislative question, and a generalization of details.

As a minor instance, we are referred to the Table of Ages of Offenders, in which the present classification is purely arbitrary and unmeaning; commencing with "under twelve," to which no significancy can be attached, and afterwards proceeding merely by decades. Considering that since the reformatory process has been substituted for punishment, the principle of *doli incapax* is rarely applied much beyond the age of *eight years*, and that sixteen is the limit of jurisdiction under the 'Juvenile Offenders' Acts,' the first period in the classification of ages should be from eight to sixteen; and as the persons who have given most attention to the subject are of opinion that those who pass beyond twenty-one without the commission of crime, rarely fall into criminal courses afterwards, the next period should be from sixteen to twenty-five; the next (the passions and temptations being still strong) might be from twenty-five to thirty-five; the next—in which there are rarely any general causes beyond previous bad habits—might be from thirty-five to fifty; and from fifty upwards, the first commission of crime (at every age which it would include) is the result of accidental circumstances. In Prussia the classification is "under sixteen; sixteen to twenty-four; twenty-four to forty; forty to sixty; sixty and upwards." Either of these arrangements would reduce eight unmeaning divisions (as at present) *to five which have some significance*; and it is suggested that on this principle every return should be made.

The enumeration of *offences* might also, it is thought, be much abridged, both in the returns and in the tables which form so large a portion of the 'Judicial Statistics, Part I,' prepared at the Home Office under the able superintendence of Mr. Redgrave. In Prussia they are classed:—"1. Riot and tumult with acts of violence. 2. Mutinous risings of prisoners with acts of violence. 3. Coining. 4. Wilful perjury and subornation of perjury. 5. Offences against decency. 6. Murder. 7. Manslaughter. 8. Infanticide. 9. Causing miscarriage. 10. Serious bodily injuries. 11. Poisoning. 12. Serious thefts, first offence. 13. Serious theft, repeated offence. 14. Robbery with force. 15. Forging documents. 16. Fraudulent bankruptcy. 17. Wilful burnings and other like offences dangerous to the community. 18. Offences in official situations. 19. Other offences not included in the above." There is similar brevity and meaning in the Prussian classification of *occupations or callings*; but here a good deal must depend upon national character and pursuits; and for ourselves, perhaps, our own classification is preferable.

From the French returns, it is suggested that we might take with advantage some notice of the effect of extenuating circumstances admitted by a jury in reducing punishments. But the point chiefly dwelt upon is the necessity of knowing more than we learn at present of a prisoner's character and antecedents. In No. I. of the new tables, the police are required to furnish, "as far as is known," the number of previous commitments; and in No. II. the "age, sex and birth-place." The information as to previous commitments is, at present, a good deal taken from the statements made to the chaplains and gaolers by the prisoners themselves, and is therefore little to be depended upon; and the birth-place of a prisoner is of less importance than to ascertain correctly whether the crimes committed in any particular district are by residents or non-residents. When there is an increase in the former, it is a proof that

there is something in the social state of the locality which requires to be remedied; if in the latter, it is merely a matter for the police, or probably accidental. The information on these points should form part of the *police returns*, and should be carefully collected, together with the number of times which the offenders have, in each case, been charged with crimes, whether proceeded against or not; and if not, for what reason. With this view a new Table is proposed, in the form annexed.

To obtain more accurate knowledge as to the criminal classes generally, it might be desirable to adopt the *Casiers Judiciaires*, which have been established in France since 1851. They are placed in various localities—one of them in each judiciary *arrondissement*. Notices are there sent and classed, of every sentence of the different tribunals of the empire (*soit du continent, soit des colonies*), against any individual belonging to any part of a district of which the locality where the *casier* is established may be considered as the centre. Of these there are 361. If it be wished to ascertain the antecedents of any individual, application is made to the clerk (*au greffe du tribunal de première instance*), by whom the *casier* for the district to which the party belongs, is kept; and a notice is returned, stating that he either has, or has not, been reported as a criminal; and if reported, how often and under what circumstances. A central office takes cognizance of foreigners and persons whose birth-place is unknown. The police find in these establishments one of the most valuable and ready modes of obtaining information*; and they appear to be a much more reliable source than the revelations made, as with us, by the criminal himself in his interviews with the governor or chaplain.

It is stated in the Report that the 'Judicial Statistics, Part I.,' prepared at the Home Office, for 1856, show a continued approach to whatever is most valuable in the best returns which have hitherto been devised: that for still greater improvements we shall find the materials in our police offices and courts of petty-sessions; and that it is principally from these sources, if carefully and faithfully watched, that we can derive a better knowledge of the classes whom we have to punish or reclaim. It is not thought desirable, however, till our arrangements are more perfect, to require complicated returns either from the prison officers or the police. The great object should, in the first instance, be to make them reliably correct.

Proposed New Table, for the Police.

(Taken from the 'Journal of the Statistical Society,' vol. i. (1839), p. 174, with some additions.)

I. Domicile.			II. Parentage.			III. Antecedents.	
Native Inhabitant.	Inhabitant not native.	Stranger.	Legitimate.	Illegitimate.	Foundling or Orphan.	Previous Charges.	Previous Convictions.

The second division is chiefly applicable to juveniles. A column of *Remarks* may be added for the remaining information required.

On Equitable Villages in America. *By* Richard H. Walsh.

These villages were established on the principle that persons were to sell articles at what they cost without any profit; the sovereignty of every individual; the adaptation of the supply to the demand; and a circulating medium founded on the cost of labour. A paper had been read before the meeting of the Association in Glasgow, in which these villages were stated to have produced a successful result. The author had however corresponded with parties in America and found that they had failed, and that very unsettled notions of family relations prevailed in them. He considered that the principles upon which they had been founded were unsound and mischievous in practice.

* Compte rendu de la deuxième Session (1855) du Congrès International de Statistique, p. 86.

On Statistics of Crime in Ireland, 1842 *to* 1856. *By* JAMES MONCRIEFF WILSON, *Actuary, Manager of the Patriotic Assurance Company of Ireland.*

The state of crime in Ireland, for the period extending from the beginning of 1842 to the end of 1856, was analysed so far as to show the classes of crime most prevalent during their course, a course made up partly of years of prosperity, but chiefly of years of adversity; and a more complete analysis was made of the state of crime for the year 1851, showing the effect of age, sex, locality, education, general occupation, intemperance and low-class house accommodation upon the amount of crime during that year.

The following are some of the general conclusions derived from the facts established in the paper:—

1. That the best measure of crime at present available is the computation of the persons committed or held to bail for trial at the assizes and quarter sessions.

2. That when a person is thus committed or held to bail, the probabilities in favour of his being convicted are about fifty-six to forty-four.

3. That no inquiry into criminal statistics can be of service unless the proportion of crime to population is taken into account.

4. That although it is impossible to state the exact population of Ireland for each year from 1841 to 1856, that still approximations not very wide of the truth may be made; and that in Table A are given about as accurate approximations to the real population in the different years referred to as could well be arrived at.

5. That want and privation are fruitful multipliers of all classes of crime, and that to such a parentage we may safely look first, when we find a general and marked increase in the crime of a country.

6. That although during the years of distress the tendency to every class of crime was greatly increased, it was chiefly offences against property, committed without violence, which swelled the criminal calendar of Ireland.

7. That in the year 1856, the tendency to crime in Ireland was certainly not greater, and perhaps less than the tendency to crime in England and Wales.

8. That the criminal returns for Ireland are susceptible of very considerable improvements, which if made, would greatly add to their value for practical purposes.

9. That among males the maximum tendency to crime for Ireland generally, and for each province separately, except Connaught, is at the period of life twenty-one and above sixteen, and for Connaught at the stage thirty and above twenty-one; and among females, for Ireland generally, and for each province separately, at the period thirty and above twenty-one; and that in both cases the minimum tendency is at the period twelve and under.

10. That the tendency to crime generally among males is only about two-fifth times the like tendency among females; but that were the petty offences against property committed without violence to be dropped, the tendency to all other classes of crime among males would be between four and five times the like tendency among females.

11. That the tendency to the class of crime termed "Offences against the person," attains its minimum among both sexes at the period of life thirty and above twenty-one; that the tendency to the classes "Offences against property committed with and without violence," reaches its maximum among females at the same period, but among males at the earlier stage twenty-one and above sixteen; that the tendency to the class "Malicious offences against property," is at its maximum among both sexes at the stage twenty-one and above sixteen; and that the tendency to the classes "Forgery and offences against the currency," and "Offences other than those before enumerated," is at its maximum also among both sexes at the period thirty and above twenty-one.

12. That among both sexes the tendency to each separate class of crime is at its minimum at the period of life twelve and under.

13. That popular education singly, but especially when combined with occupation, tends powerfully towards the diminution of crime.

14. That the good effects of education and occupation upon crime are very seriously marred by the abuse of intoxicating drinks.

15. That low-class house accommodation tends towards the increase of crime.

16. That popular education, as a means of diminishing the tendency to crime, although most useful in so far as both sexes are concerned, has yet much greater effect among females than among males; and that is emphatically the case in regard to four classes of crime, "Offences against the person;" "Offences against property, committed without violence;" "Malicious offences against property;" and "General offences," class No. 6.

17. That ignorance among the masses operates injuriously among the educated and half-educated classes; and that, therefore, to educate the ignorant will tend not only to lessen crime among them, but also among the better classes thus influenced.

18. That were intoxicating drinks less freely used, education as a means of reducing crime, would become more powerful.

19. That the average tendency to the class of crime "Offences against property committed without violence," is rather more than one-half the average tendency to crime generally.

20. That, as without doubt, a large proportion of the serious crimes are committed by those who in early life may be said to have served an apprenticeship to theft; and that as this (No. 3) class of offences, at the period of life sixteen and above twelve among males, amounts to three-fourths of the whole male crime, and among females to five-sixths of the whole female crime, it follows that by getting reduced at this period of life such offences, the more serious crimes at later stages of life will also necessarily be diminished.

21. That increasing efforts should be made to educate all classes of the youth of both sexes; and that instructors ought not to rest satisfied with merely teaching to read and write; but that in all our schools industrious habits should be constantly taught, cleanliness and morality daily enforced, and the danger of indulging to excess in the use of intoxicating drinks frequently pointed out.

On Deferred Annuities. By CADOGAN WILLIAMS.

On Annuities on Lives. By CHARLES M. WILLICH.

On a Formula for ascertaining the Expectation of Life. By CHARLES M. WILLICH.

On the Application of the Decimal Scale in the Construction of Maps. By JAMES YATES, *M.A., F.R.S.*

Since the commencement of the present century the various continental nations have to a great extent adopted the principle of constructing their maps upon a decimal scale. I will briefly notice some of the most remarkable examples that have come to my knowledge.

In France, the adoption of this principle is an obvious and even necessary result of the introduction of the metre as the unit of length. Millimetres, centimetres and decimetres are, as a matter of course, made to correspond in maps to kilometres, or other decimal multiples of themselves, on the surface of the earth.

Hence one of the results of the annexation of Algeria to France has been the production of excellent plans of cities and maps of the whole country, all decimally projected, and consequently either identical in their scale, or related to one another by clear and simple proportions*.

In Belgium this important task has been taken out of the hands of the Government and admirably executed by M. Van der Maelen, proprietor of the celebrated Geographical Institute. He has published a general map of Belgium, the scale of which is 1 to 200,000; and another, the scale of which is 1 to 20,000 (Brussels, 1846), consequently ten times the dimensions of the preceding.

Sardinia is most honourably prominent in labours of this class. Its Government

* 'Carte de la Province d'Alger,' 1838. Scale 1 to 400,000. 'Environs de Blida,' 1838. Scale 1 to 20,000. 'Plan d'Alger et de ses Environs,' 1832. Scale 1 to 2500.

has published beautiful maps, both of the island of Sardinia and of the continental territories, on the following scales, $\frac{1}{2,000,000}$, $\frac{1}{800,000}$, $\frac{1}{500,000}$, $\frac{1}{250,000}$, $\frac{1}{50,000}$, $\frac{1}{25,000}$.*

Germany has adopted the same method, although it has not yet obtained the full advantage of using the metrical system for commerce and other ordinary transactions. The kingdoms of Bavaria and Wurtemburg and the Electorate of Hesse Cassel, together with some of the neighbouring duchies, employ the General Staff of each country in executing maps on the same scale, which is that of 1 to 50,000. Thus the maps of these several governments fit one another like the dissected maps of our English counties. There is also a Topographical Atlas of Bavaria, the scale of which is $\frac{1}{800,000}$, published in 1843.

Spain and Portugal have decreed that the metrical system shall after a few years be exclusively employed for weights and measures in those countries; so that it must ere long be employed for the government maps, if it has not been adopted already.

It thus appears that the whole of the west of the continent will shortly be described and delineated in maps and plans adjusted to one another and capable of easy comparison, in consequence of being all projected with dimensions decimally related to the surface of the land.

Of the scales employed in our own Ordnance Surveys, 1 inch to a mile and 6 inches to a mile, the former is the 63,360th part of the actual linear distance, the latter is the 10,560th part. It is very difficult and inconvenient to calculate by either of these numbers. On the contrary, the decimal method will be found easy in its application to this as well as all other purposes. Either a metre, or any other measure of length, which is decimally divided, may be applied to the map, and will show the real distance from one place to another with the greatest facility. Thus, if the scale be 1 in 10,000, a decimetre on the map will represent a kilometre on the surface of the ground; and if it be $\frac{1}{5}$th less, or 1 in 50,000, as is the case in many of the maps which have been mentioned, a kilometre on the surface of the ground will correspond to two centimetres on the map.

If the decimal scale has advantages as regards the maps of the British Isles, considered by themselves, still greater benefit will arise when they are to be compared with maps of the neighbouring territories on the continent. We have already advanced so far towards uniformity as to sanction one scale for all England and another for all Ireland, and some persons think it would be well to apply the same scale to the whole of the British Isles. But why should not the principle of uniformity be carried further? If the decimal scale has great intrinsic advantages, it must be an additional reason for its application, that it would bring our maps into coincidence with those of our continental neighbours.

In England the decimal principle has scarcely been applied at all to the construction of maps. There is, however, an exception to the universality of this remark in the case of Mr. W. Hughes, F.R.G.S., whose 'Geological Map of the British Islands' is projected on a decimal scale, every line and every distance upon it being to the corresponding distance in nature, as 1 to 2,500,000. Its proportions are consequently $\frac{1}{50}$th of the proportions adopted in the national maps of Germany†.

* Gran Carta degli Stati Sardi in terra ferma divisa in fogli 91, alla scala di $\frac{1}{50,000}$, 1852.

Carta degli Stati di S. M. Sarda in terra ferma, ridotta all $\frac{1}{500,000}$, 1846.

Government Map of Piedmont and Savoy, scale $\frac{1}{25,000}$, 1841.

Carta dell' Isola e Regno di Sardegna, scale $\frac{1}{250,000}$, 1845.

Also small one of the above, scale $\frac{1}{2,000,000}$, 1845.

† A Report, which was presented by Dr. Farr to the International Statistical Congress at Vienna, in August 1857, contains the following information:—

"Conformément aux recommandations du Congrès de Bruxelles, le Gouvernement de sa Majesté Britannique s'est determiné à faire dresser des cartes générales à l'échelle de 1000–2500, et des cartes des villes à l'échelle de 100–500. Déjà les cartes de plusieurs comtés et de plusieurs villes ont été dressées sur ces échelles. Ce travail a été malheureusement suspendu. Les avantages qu'offrirait une carte de l'Europe à une échelle uniforme sont évidents: ils ont été démontrés à la Chambre par le Vicomte Palmerston; et nous croyons qu'ils seront appréciés par la commission royale qui est chargée de l'examen de la question."

On the Use of Prime Numbers in English Measures, Weights, and Coinage. *By* James Yates, *M.A., F.R.S.*

On examining the Tables of the measures, weights, and coins used throughout England, it is found that the prime numbers used in their composition and of the most frequent occurrence are 2, 3, and 5. Of these, 2 occurs as a factor by far the most frequently, indeed twice or thrice as often as either 3 or 5.

Seven makes its appearance in the following weights and measures:—

Avoirdupois Weight.

7000 grains	=1 lb.
14 lbs.	=1 stone.
28 lbs.	=1 quarter.

Wool Weight.

7 lbs.=1 clove, whence 14 lbs.=1 stone.

Wine Measure.

42 gallons	=1 tierce.
63 gallons	=1 hogshead.

Eleven is used in one case only, but that is an important one, viz.:—

Long Measure.

$\frac{11}{2}$ or $5\frac{1}{2}$ yards=1 rod or pole, from which is deduced 4 poles, or 22 yards=1 chain. The furlong, the mile, and the acre are also multiples of this fundamental number.

Thirteen also comes in once as a factor, viz. in

Wool Weight.

$\frac{13}{2}$ or $6\frac{1}{2}$ tods . . . . =1 wey.

Wool weight is curiously compounded. No less than four primes, 2, 3, 7, 13, are used as factors, producing only six denominations, which are as follows:—

1 clove	=7lbs. avoirdupois.
1 stone	=2 cloves.
1 tod	=2 stones.
1 wey	=$6\frac{1}{2}$ tods or 13 stones.
1 sack	=2 weys.
1 last	=12 sacks.

Only one other prime number requires notice, and that is found in a very conspicuous position, and where, perhaps, it was little to be expected, viz. in a recent Act of Parliament. The law now in force and known as the Weights and Measures Act, fixes the number of grains in the lb. avoirdupois by the use of the number 7, and goes on to determine the relation of the pound troy to the standard linear measure by declaring, that a cubic inch of distilled water "is equal to 252 grains and 458 thousandth parts of a grain." If this number $\left(\frac{252\cdot458}{1000}\right)$ be divided by 2, it will be found that a cubic inch of water weighs 126·229 five hundredth parts of a grain, the numerator of this fraction, $\frac{126\cdot229}{500}$, being a prime number.

As the result of this analysis, it appears that the primes used in the English measures, weights, and coins are the following:—

2, 3, 5, 7, 11, 13, and 126·229.

I propose to offer a few remarks respecting the aptitude of these numbers for the functions which they are appointed to perform.

The adoption of them does not appear to have been determined, in any case, so far as we can judge, by reason or principle, but to have arisen from accidental and arbitrary causes. There is no apparent benefit in connecting our highest coins by 2 and 5, the intermediate by 2 and 3, and the lowest by 2 only. No advantage arises from measuring land by elevens, and weighing wool by sevens and thirteens. No reason can be assigned why seven should be brought into avoirdupois weight and excluded from troy weight; or why 3 should be excluded from avoirdupois weight, whilst it plays an important part in troy weight and apothecaries' weight. In short, all our Tables present the appearance of an entire want of principle in their construction.

The introduction of an additional prime has the effect of making our weights and

measures more complex and multiform. It ought therefore to be avoided, unless some necessity can be shown in its favour. Hence it would seem to be expedient to abolish from these calculations all primes except 2, 3, and 5; and here an important question arises, viz. should these be retained, or shall we be satisfied with 2 and 5, omitting 3?

We are thus brought to one of the great discussions of the present day, the expediency of decimalizing our measures, weights and coins.

The consequence of the simple fact, $2\times5=10$, is, that all decimal systems are also binary and quinary, the principal quantities expressed by tens, hundreds, thousands, &c. being divisible by 2 and by 5 without remainder, so that their doubles and their halves can be introduced and reckoned without the least difficulty or inconvenience. But such systems do not readily admit the number 3, because in the majority of cases the quantity cannot be divided by 3 without a remainder, and in many cases the division by 3 produces a repeating decimal. This is the ground on which many persons have insisted on 12 as a multiplier for measures, weights, and coins, rather than 10. But it is to be observed, that if 10 cannot be divided by 3, on the other hand 12 cannot be divided by 5 without remainder. Hence it seems to follow, that the choice must be made between decimal and duodecimal modes of computation, according as a preference is given to 3 or to 5 as a divisor. If it is more necessary or convenient to divide by 3 than by 5, duodecimal methods are entitled to the preference, so far as this circumstance is concerned. I cannot, however, discover any reason for making this assumption. I think it probable, that division by 5 is required as frequently as by 3, whilst every other consideration is decidedly in favour of the decimal scale.

The investigation which we have been pursuing is, therefore, first, in favour of decimal measures, weights, and coins; and secondly, supports the views of those who think that the subordinate multiples and divisions should be made by 2 and 5 only, and not by 3.

In this conclusion I have the satisfaction to observe that I am countenanced by the authority of the late Mr. Drinkwater Bethune, one of the Commissioners appointed by the present Lord Monteagle, when Chancellor of the Exchequer, to consider the steps to be taken for restoring the standards of weight and measure. In his letter to the Chancellor of the Exchequer, dated 21st of September, 1841, he maintains the following positions:—

1st. That "the Tables of Weights and Measures now in use are complex and inconvenient, and that it is very desirable to get rid of inconvenient multiples such as the factor 7, which connects the pound avoirdupois with the stone, and thereby with its multiples, the hundredweight and ton; and the factor 11, which connects the yard with the chain, and thereby with the mile and acre."

2nd. That "it is desirable, that no numbers, which are not multiples either of 2 or of 5, should anywhere appear in the Tables."

MECHANICAL SCIENCE.

Address by Lord Rosse, *the* President *of the Section.*

Lord Rosse commenced by apologizing for any oversight he might commit, as he had never at any previous Meeting of the British Association presided over the Mechanical Section. He was happy, however, that there could be no danger of serious errors on his part, as there were able men on both sides of him who had made Civil Engineering their special study. He proceeded to say that the question had sometimes been asked why a Mechanical Section was necessary; might not all mechanical questions be conveniently discussed in the Mathematical and Physical Section? To that question, on some occasions, an answer has been returned. It may at once be said, that it has been found eminently useful to have separate Sections for each distinct department. It is only under such an arrangement that discussion can be really effective in bringing out new truths. If a considerable portion of the Section is not intimately acquainted with the subject in all its details, what prospect can there be of

new and sound views being elicited; and indeed if the whole Section has not some general knowledge of the branch of science which has been committed to its care, what hope can there be that discussions will be heard with interest, and will have real efficiency in awakening and strengthening a taste for science? This has been felt, indeed strongly felt, at the Royal Society, where there are no Sections, and the subjects are of a very varied nature, comprehending the whole range of the Mathematical and Physical Sciences, and all the Natural Sciences. A paper perhaps is read on Pure Mathematics: very possibly there may not be in the room at the time more than two or three persons who are intimately acquainted with that branch of science: a discussion of course is out of the question. A paper follows on one of the Natural Sciences: if there are a few who are working in that direction a discussion takes place; but it is of little interest even to those engaged in other branches of Natural Science; and almost, if not altogether without interest to the Mathematician, the Chemist, the Astronomer, the Geologist, and the Physicist. So it rarely happens that there is a discussion at the Meetings of the Royal Society, of general interest or of real value; and for that there is no remedy. Here, by the happy expedient of breaking up the Association into separate Sections, the way has been prepared for discussing subjects in that effective manner which, originating with the Geological Society, has already so much advanced geological science.

Where one of the great objects of these meetings is to elicit truth by discussion, it is evident how unwise it would be to group together in one Section a variety of subjects, each requiring special studies, a special line of thinking, and special experiences. In Section A, human ingenuity and human knowledge are employed in the solution of mathematical and physical problems; while in Section G, human ingenuity and human knowledge, but of a different kind, are employed in the solution of questions of practical engineering. This may so far perhaps be considered, in one sense at least, a sufficient answer to the question, why is a Mechanical Section necessary? The question, however, may be put in another sense. Where the investigations are not abstract, but practical, and where the results generally are of immediate interest, is it necessary that the British Association should interfere at all? Will not private individuals, from motives of self-interest, devote themselves to the pursuit of Civil Engineering in its higher branches, without any adventitious stimulus? Will not public men, seeing that the interests of the State, both in peace and war, are bound up with the full development of the resources of engineering, make it their business to acquire such a general knowledge of the subject as will enable them to ascertain when and where to apply for aid in time of difficulty? The reverse unfortunately is the case; experience has shown that men, whether in their private or public capacity, do not act in these matters exactly as we should expect; they do require both to be aided and urged forward.

In this eminently practical country, private individuals, very often relying on experience, neglect the means necessary to render calculation effective. Experience, however, is not always at hand, and is often very costly. How often do we see the ingenious mechanic working on false principles, vainly perhaps attempting to accomplish something which a little elementary knowledge would have shown to be impossible! There are perhaps few gentlemen present who could not point out instances where individuals had sustained heavy losses from the want of adequate theoretical knowledge. In his limited experience he had known several. This perhaps is a striking one. Some years ago he was invited by a physician of eminence in London to visit the works of an ingenious mechanic, who was endeavouring to employ air heated by gas as a prime mover. The physician had embarked £12,000 in the project; a lady of wealth had speculated in it to the extent of £30,000; and various individuals had advanced sums altogether to a large amount. At the entrance of the premises there was the wreck of a gigantic machine of unknown construction: other machines in a dilapidated state were lying about in all directions. It appeared from the explanation of the mechanic, that these huge masses of ruined machinery had been constructed partly for the purpose of ascertaining facts to be found in every elementary treatise, and partly for the accomplishment of objects manifestly impossible. In the construction of the engine itself there was a striking display of great ingenuity constantly engaged in a struggle with the laws of nature. It was perfectly evident that the whole was fated to end in disappointment; still the mechanic and his patrons,

undismayed by repeated failures, and heedless of warnings, which, where there was no science, were without force, struggled on till the project came to an end from exhaustion. Some of the parties were ruined, while all lost the capital they had embarked in the speculation.

One of the objects of the Mechanical Section is to prevent such disasters, and no doubt to a certain extent this has been effected. Another object has been effected also: the importance of engineering science in the service of the State has been brought more prominently forward. There seems, however, something still wanting. Science may yet do more for the navy and army, if more called upon.

A few years ago, in sailing through the harbour of Portsmouth, as the boat proceeded along, the sailors gave a little history of each ship laid up there; they said, That ship has been but once at sea, and it rolled so it was almost impossible to keep masts in her; she is not likely to go to sea again. There is another ship which sails so badly that she can neither chase nor run away. There is a ship which can scarcely beat to windward, and if it was blowing hard upon a lee-shore, she would have but little chance. Other ships had other defects. Strange uncertainty: who could avoid asking the question, is naval architecture really guided by science? About that time a little book came out which solved the mystery. It is called 'Lectures on the results of the Great Exhibition:' the lectures are by first-rate men. In it there is a lecture by Captain Washington, "On the Progress of Naval Architecture," an officer of high scientific attainments, now Hydrographer to the Admiralty. After mentioning the well-known historic fact, that during the late great war our best ships were copies, and not always very successful ones, of foreign models, he proceeds to say, that all who served in the blockading fleets were painfully alive to the fact that our ships were inferior to those of France and Spain in speed, stability, and readiness in manœuvring. That much loss of life might have been spared if our ships had been in form more on a par with those of our opponents. He attributes their inferiority to the fact, that while in France and Spain, and other continental countries, the aid of science had been called in, and the greatest northern nations had turned their attention to ship-building, the only English treatise at all of a scientific character was published by Mungo Murray, who died a working shipwright. That England has not to this day one original scientific treatise on Naval Architecture. He further states, that of the forty-two men who were educated in the School of Naval Architecture which had been established in 1811, and after a few years suppressed, but five had to this day risen to stations of responsibility, and that the sight might have been seen of men familiar with the differential calculus, chipping timber in the dockyards in company with common mechanics. Cruze, in his article on Naval Architecture in the 'Encyclopædia Britannica,' makes similar statements.

It has been objected, however, that the powers of engineering science have been overrated; that they had been brought to the test during the late war and had but little strengthened our hands. People seemed to think that scientific invention should have carried all before it. Inventions, however, do not come forth at our bidding; and are we sure there has been much to attract highly cultivated inventive powers to the science of war? Have we never heard a whisper of official prejudices and official discouragement? Moreover, if you invent, the invention soon falls into the hands of a vigilant enemy and you have achieved nothing.

It was not by little inventions that the engineering powers of England could have been brought to bear effectually in the late war. If, when war was imminent, civil engineers had been consulted in conjunction with military engineers and naval men, means perhaps would have been found by which the gigantic engineering resources of this country would have been rendered available. It was going a little too far when it was said that Cronstadt could have been taken by contract. Of this, however, there could have been no doubt, that a certain thickness of wrought iron would have resisted the heaviest ordnance then in use; that the sea could have carried the weight; and that no stone walls could have long resisted the close fire of large guns. Moreover, there were actually French experiments made a few years before, which, in the absence of new experiments, would have afforded tolerably accurate data for the necessary calculations.

Let it not be said that engineering science was almost powerless in the late war, till it can be shown that it had a fair trial,—that its aid had been called for at a proper time and in a proper manner.

It is scarcely necessary further to insist upon the importance of the Mechanical Section. It is obviously the interest of public men, no less than of private individuals, to pay increased attention to Mechanical Science. If this Section can contribute ever so little to bring out new facts, or to direct attention to facts already known, it will have rendered good service.

A detailed Model of the Boyne Viaduct which carries the Belfast Junction Railway over the River Boyne at Drogheda, with a description of it, and the Principles of its Construction. By JAMES BARTON, *C.E.*

The dimensions of this work are,—height above high water, 90 feet to soffit of bridge; open of centre span, 264 feet; of side spans, 140; besides fifteen stone arches of 61 feet span each. The three centre spans are crossed by wrought-iron lattice beams designed by the author; and the chief feature of interest connected with this work is the mode in which the results of careful investigation of the strains on every bar and plate have been practically applied. Having ascertained the maxima strains, whether tensile or compressive, that each bar could be subjected to by the weight of the structure, combined with the passing load entire or in part, the areas of iron and the form of the parts were then designed and made proportionate to their maxima strains; the limit assumed being that no part should ever be subjected to more than 4 tons per inch of iron of compressive, and 5 tons per inch of tensile strain, and that the parts under compressive strain should be so arranged and braced that they should not yield by flexure.

The three spans are crossed by a continuous beam; and the author explained how this arrangement, whilst it was economical and decreased deflection, involved much more complicated calculation. He showed when the points near the top and bottom of the beams, called the points of inflection, were under different states of the load, and how these points travelled along as the load passed over, these points being points at which there is no strain of either tension or compression, the top and bottom on either side of these points being under opposite kinds of strain.

The iron used for this structure was much less than ever the same spans had been crossed with before by any Girder Bridge, and was at the same time as strong as any. The total iron used was 740 tons, and the cost complete was about £24 10*s.* per ton as it stands, exclusive of scaffolding below the ironwork. The iron was from Staffordshire; that subject to a tensile strain, of the quality known as "*best best*;" that only subject to compression, of the quality termed "*best iron.*" The correctness of the calculations, had been proved in some remarkable ways: the points where theoretically there should be no strain in the top under a uniform load having been determined for the large span of 264 feet, the author, after the bridge was relieved of its supports, severed the top of the main beam in these places, and the strict maintenance of equilibrium in the structure proved that no strain was then passing through the open joints of the ironwork. Again, it was calculated that when a load of 2 tons per foot forward would be put upon the centre span, in addition to its own weight, the points of inflection of the side spans would pass the ends of the beams, the result of which would be that the side spans ought not to rest any longer on the abutments of masonry, but stand out as overhanging beams from the piers between them and the centre span. This actually took place; and when the centre span was thus loaded, the ends of the side spans were found to have lifted 1 inch off their bed plates and rollers; nor did they descend until a locomotive from the centre span travelling along the side span from the centre came within about 40 feet of the end. The bridge had been tested with 1100 tons and in a variety of ways, and the results were most satisfactory.

On Coal-burning Engines. By J. S. BEATTIE.

On Electro-Magnetic Engines. By J. S. BEATTIE.

On Improvements in Ordnance. By Captain BLAKELEY, *R.A.*

A 16-inch shot would present but 16 times the surface to the action of the air (to retard it, or make its flight inaccurate) as a 4-inch shot, and would weigh 64 times as much; it would therefore be retarded and blown out of its course but $\frac{16}{64}$, or $\frac{1}{4}$ as much.

A gun four times as accurate as a 9-pounder, and with the immense range due to the less resistance of the air, would be a powerful weapon on board fast steamers. A few 30-inch shell guns would be useful in war, and really conducive to peace if placed on the banks of the Thames, the Clyde or the Mersey. If any foreign power quarrels with us and suddenly appears with thirty or forty gun-boats armed with one monster gun each, he could destroy Portsmouth. None who know Mr. Armstrong's application of hydraulic power will doubt its adaptability to move guns of any size, and with little human labour. Large guns require more strength than small ones, as the powder occupying in each the same proportional space, the small shot moves in say $\frac{1}{300}$ of a second a certain number of inches, the large shot in the same time moving fewer inches, so that at the end of that time the gas in the small gun would have *much* more proportionate room to expand in, and would therefore press less on the gun than in the large one. Added to this, the large shot would require more time to get its velocity, and the pressure must remain on the gun so much longer. May not the *time* a material can bear a tension be an element worthy of experiment; and may not cast iron bear a pressure during $\frac{1}{200}$ of a second, which if continued during half a second would destroy it? I believe the sudden and short strain caused by the explosion of gunpowder to be less, not more injurious, as is generally thought, than an equal strain applied gradually but left longer. However, a 32-pounder is the limit of cast-iron guns of the present shape, any larger than that being unsafe with full charges. Adding thickness to the metal would give little additional strength. Professor Barlow calculates that a cylinder one inch thick, and one inch in internal diameter when strained, stretches only $\frac{1}{9}$ as much in proportion outside as inside, the cross section remaining equal, so that the interior diameter being stretched to $1 \times \frac{1}{1000}$, the exterior, instead of becoming $3 \times \frac{1}{1000}$ (as it would if the outside layer "*put out*" an equal strength to the inner, according to the law "ut tensio sic vis"), becomes only $3 + \frac{1}{9}$ of $\frac{1}{1000}$ or $3 + \frac{1}{3000}$. The cross section being $(3 + \frac{8}{3000})^2 = 9 + \frac{1}{500}$ minus $(1 + \frac{1}{1000})^2 = 1 + \frac{1}{500}$; the difference, 8 round inches, being the same as when not strained, or $(3^2 - 1^2)$.

If with the present thickness the outside does but $\frac{1}{9}$ its duty, we can expect but little additional strength from adding to it; Professor Barlow arguing that the strength decreases as the squares of the distances from the centre. The same law puts a limit to the size of brass or cast steel guns, or of wrought iron if in one welded mass.

I would suggest for guns up to 10 inches a shape very like the present, but the outside at the breech strengthened with two layers of thin wrought-iron cylinders put on very hot, and hammered so that the outside shall be fully strained when the gun is fixed. One I made so stood 605 rounds, all with double charge, and the last 158 rounds loaded to the muzzle. This is evidently greater strength than is required for anything under 10-inch guns. Above that, I think, with a cast-iron cylindrical centre, that either rod-iron wound round at a great heat and welded, layer over layer, but each in cooling taking a permanent strain, or else iron wire wound round it, each layer having a greater initial strain than the one under it, would be the best way: we thus get all the fibre in one direction.

Mr. Armstrong of Newcastle made a gun of a solid steel centre, with bar iron coiled round it and welded. This gun has stood some thousands of rounds. I discovered early in 1855 that Mr. J. Longridge, C.E., agreed very nearly with me in opinion, having arrived quite independently at his conclusions, and since then we have been working together. I exhibit some brass cylinders strengthened with wire, which he experimented on; the strain cannot have been under 56 tons per inch on some of these, reckoning brass and wire, or at least 70 tons an inch on the wire, as there the strength lay. This would make very serviceable field howitzers; such howitzers need not weigh over 8 cwt.

If we do not possess the most efficacious weapons possible, we shall find ourselves overpowered some day. Any foreign power could secretly prepare a flotilla of gunboats, and manufacture the large guns to destroy our fleets and seaports immediately after a declaration of war.

On the Working and Ventilation of Coal Mines. *By* JOHN BRAKENRIDGE.

It was recommended, that instead of commencing to get coal when the straight-works and board-gates were only partially completed, coal-owners should drive the board-gates to a cross heading at, or nearly at, the extent to which it might be proposed to work and draw the coal by the same engines and pits, and that the upcast pit should be sunk, and the furnaces for creating a draft placed at the highest point in the bed of coal. Then that from this cross heading the coal should be got in the opposite direction, *i. e.* toward the downcast pit, instead of from it as at present, and thus the danger would be greatly abated.

By such mode of working, the ventilation would be more natural; a considerable portion of the gases would be liberated and discharged from the coal before the wide works in the banks were begun, and the current of the gases as they exude from the coal or the roof would be upwards from the men and towards the upcast pit, by which they would make their escape; the whole mine would then be less liable to become inflammable and explode.

All the precautions practised in the present mode of working would be necessary in this, but in a less degree, and the safety of the mine would depend less upon them; and should an explosion unfortunately happen, it would be behind the men, and the force of it would be towards the upcast pit, giving the men the almost certainty of escape towards the drawing pit, through the passages in the solid coal. The sacrifice of human lives, as well as much of the damage to the mine, would therefore be in a great measure averted.

A Plan for Diminishing the Strain on the Atlantic Cable by an Elastic Regulator. *By* C. BROOKE, *M.A., F.R.S.*

The proposed plan consists in suspending a block with one sheave of the same size as the paying wheels by a bundle of parallel cords of vulcanized india-rubber from a boom rigged to the mast. This elastic bundle should be of sufficient length and thickness to elongate 10 or 12 feet, by an increase of strain from perhaps four to six tons; and should be placed vertically over one of the pairs of paying wheels, and the cable move through it between the wheels. As the cable is double, the bundle will be required to bear twice the strain of the cable. By this arrangement, from 20 to 24 feet of cable would be given out by an increase of tension of from two to three tons, and taken up again as soon as the tension is diminished.

On Improvements in Iron and Steel, and their Application to Railway and other purposes. *By* J. W. DODDS.

On Macadamized Roads. *By* G. H. FRITH, *C.E., County Surveyor.*

The author presented a compendious review of road-making, especially in Ireland. He points out evils in the prevalent systems of road-making; treats of the proper magnitude of the stones required for mending, the influence of weather on the process, the obstacles of various kinds to good road-making, and gives a specification for keeping in repair a certain portion of road near Dublin, by which a large annual saving was effected. Reference is made to continental as well as English authorities.

On the Effect of the Resistance of Water to an Extended Cable. *By* A. S. HART.

On Controlling the Movements of ordinary Clocks by Galvanic Currents. *By* JOHN HARTNUP, *F.R.A.S.*

Since the application of electricity to the purposes of the telegraph, various methods have been had recourse to for working clocks at distant stations by a normal clock at an observatory; or by causing one clock in a large establishment to work several sympathetic clocks in different parts of the building. The advantage of being able to make several clocks show the same time as a normal clock regulated by astrono-

mical observations, or by the transmission of time signals from an observatory, must be admitted to be great; but those who have had much practical experience in the matter are aware of the serious drawback, which in spite of every precaution will occasionally arise, from failure in the galvanic current, and which necessarily causes all the sympathetic clocks to stop. The members of the British Association for the Advancement of Science will be gratified to hear of an invention, which sacrifices nothing in point of accuracy, and which is nevertheless perfectly exempt from the objection to which we have alluded.

For the discovery of this simple and very beautiful method we are indebted to Mr. R. L. Jones of Chester, and the first application of it to a large public clock was to that of the Liverpool Town Hall. This clock being appealed to by the merchants on Change as the standard of time, had subjected them to great inconvenience by its *irregular performance*, and at my recommendation the plan of Mr. Jones has been adopted with perfect success. The clock in its present state, with the improvements which have been made, differs in no respect from an ordinary old turret clock, except that the pendulum-bob is a hollow electro-magnetic coil which passes around permanent magnets at each oscillation. At each transmission of a current from our normal clock at the observatory the coil itself becomes a magnet, and the attraction or repulsion between it and the permanent magnet prevents the pendulum from oscillating except in *strict conformity* with the pendulum at the observatory. The wire which connects the Town Hall clock with the clock at the observatory is about one mile in length, and the controlling power is so great that a single cell of a Smee's battery charged with very weak acid is sufficient to control the movements of the Town Hall clock, even when the pendulum is lengthened or shortened so as to make it lose or gain several minutes a day when not under the control of the clock at the observatory. In practice, however, the pendulum is regulated to correct time as near as possible, so that in the event of the current failing, the clock will not only continue to go, but it is liable to the errors only of an ordinary clock, and as an error so small even as a fraction of a second is sufficient to show that the current is not controlling or acting, the fault may be detected and the remedy applied before the public are subjected to any inconvenience.

By this method, therefore, it is quite practicable to make all the public clocks in a town, or any number of clocks in a large building, strike, or keep the same time to a fraction of a *second*, without the risk of inconvenience by failure of the electric current, since all the clocks would go as ordinary clocks should the current fail. This method of controlling the pendulum of a large public clock has been in operation at Liverpool for several months past, and the public have an opportunity each hour of the day of witnessing the efficiency of the method. In the office window of the Magnetic Telegraph Company, which is within a few yards of the Liverpool Town Hall, there is a sympathetic seconds clock, the face of which is exhibited to the public. This clock is worked by our normal clock at the observatory, and as the seconds hand, at the end of each hour, falls upon the sixtieth second, the first blow of the hammer of the Town Hall clock breaks upon the ear, much to the admiration and astonishment of a large number of persons who congregate daily to witness this novel performance.

The normal clock at the observatory is an ordinary astronomical clock, the contact springs of which are so slight as not to interfere sensibly with its performance. It will therefore be seen, that by placing a good astronomical clock in any building, a turret or any number of clocks may be connected and their movements controlled by it, and a degree of accuracy secured which has hitherto not been attained.

On the Mode of rendering Peat economically available as a Fuel, and as a Source of Illuminating Gas. By J. J. HAYES.

On the Use of Percussion Lights for preventing Collisions at Sea and on Railways. By Captain LEACH, *R.E.*

The author introduced the subject by adverting to the fearful loss of life and property which annually occurs from collisions at sea; and to the well-known fact that these collisions generally arise from the want of a proper look-out on board one or

other of the vessels; and alluded also to several recent cases of collision, in which it was subsequently shown that one of the vessels had seen the other in sufficient time, and at a sufficient distance, to have averted the calamity had the means been at hand of instantly giving warning of the danger in such a manner as to have attracted the attention of the people on board the approaching ship.

Captain Leach suggested that for this purpose every sea-going vessel should be compelled to carry brilliant percussion lights, to be used as "danger signals," which would ignite on being struck against any hard substance; and that the officer of the watch, or other person in charge of a ship, should be held criminally responsible that these signals were ready for instant use in lockers placed on deck in suitable situations.

He pointed out, that, besides indicating danger, these lights, by the use of four different colours, might be made to show whether a vessel was at anchor or in motion, and her course upon any one of the eight principal points of the compass; or, if a more simple code of signals was considered desirable, that two coloured lights, and a white light, used singly, would be sufficient to make known the tack on which a ship was steering, or whether she was stationary; and observed that such lights, which would not be costly, and would be always at hand in case of danger, might be made sufficiently brilliant, and of such an illuminating power as could not fail to attract the attention of the helmsman, even supposing the look-out to be asleep or otherwise neglecting his duty.

It was not proposed to interfere with the existing lights carried by sea-going vessels, but to use the percussion lights as "danger signals" only.

Captain Leach also recommended the use of percussion lights by railway companies, and drew attention to several cases of collisions on railways which could not have occurred had the guards of the disabled trains possessed such a means, in addition to their ordinary signal lamps, of making the drivers of the following trains aware of their danger.

Early Methods of Propelling Ships. By JOHN MACGREGOR, *M.A.*

Almost every method of marine propulsion has its type in means employed by sea-water animals, and among these may be specially noticed:—

1st. Arms, legs, fins, tails, paddles, membranes or cilia, with a reciprocating motion feathered in the water, as by water-beetles, amphibious animals and fish.

2nd. Water forced through tubes, as by the cuttlefish and paper nautilus.

3rd. Creeping motion by whelks. "Sooping" motion by the Pedipes. Creeping and swimming combined by the Lepidosiren.

4th. Screw propeller motion, by the *Paramecia vulgaris* (in which an undulation or protuberance moves round its oval-shaped body spirally*).

5th. [Propulsion by sails†, as by the "Portuguese man-of-war" and aquatic birds.]

Marine propulsion methods may be classified according to

The power used and machinery employed.

I. Muscular power, (A.) of men, (B.) of animals.
II. Expulsion of gas or water against air or water.
III. Springs, weights, gunpowder, capillary attraction, wind and other motions.
IV. Endless chains and revolving wheels.
V. Submerged propellers.
  (a.) Feathering oars, collapsing vanes and sculling oars.
  (b.) Feathering paddle-wheels and screws.
VI. Submarine vessels.
VII. Steering apparatus and directors.

(A.) *Propulsion by muscular power of men.*

The methods arranged progressively.

(1.) Swimming without artificial aid.
(2.) Webbed fins or hooks on the limbs, as proposed by Borelli (A.D. 1683), to enable the diver "to swim like a frog or creep like a crab‡."

* A half-turn screw-like movement in the gauze wings of an Australian fly was depicted in the 'Illustrated London News,' August 15, 1857.

† This paper does not include propulsion by sails.

‡ See 'Marine Propulsion,' p. 15. (This book is an abridgement of the specifications of

(3.) The body swimming partly supported.

(*a.*) On skins (Nineveh marbles) or gourds (Barth's African Travels).

(*b.*) On a rope (Memoirs of Missionaries in China).

(*c.*) On a piece of ice (R. Valturius, A.D. 1472).

(*d.*) On reeds (as now in Egypt or in Tartary), where a bundle of reeds is tied to a horse's tail while the rider holds his head, swimming (Churchill's Voyages, vol. i. p. 463).

(4.) The body floating out of the water and propelled.

(*a.*) By the hand paddling (as in China*).

(*b.*) By the hand working a pole with which to push or punt, or an oar to paddle, scull or row with.

Mandan Indians' tub-shaped boat, rowed by a woman drawing a shovel-like oar inwards.

A similar oar used like a mud-rake on the Rhine.

Single oars with a sculling motion were used in Nineveh, Egypt and China, and some of them had twenty rowers to each.

Double-bladed paddles were uncommon in Egypt. They are represented in an old Japanese Dictionary in thirteen volumes, in the British Museum, and in Nicolo's Voyage in Greenland (A.D. 1380).

Two oars worked by one man were used in the ancient British coracle, but not often in Egypt or Nineveh.

A curious plan, wholly disused now, is shown in Lepsius, Denkmaeler aus Egypten, &c., by which Egyptian rowers stood facing the outside of the boat and swinging sideways, while each held two oars nearly vertical, on the same side of the boat†.

Pin rowlocks and oar-slings were used in Egypt; and the men stood or sat at the oar with one leg raised on a midriff platform‡.

(Oars have been worked by machinery moved by wind, water, rolling of the vessel, weights, springs, and steam.) One of the ships Columbus used in his voyage to America was propelled by thirty-eight oars. (A drawing is in 'Columbus' Letters,' A.D. 1493.)

"Edgar was rowed on the Dee by eight tributary kings§."

(B.) *Muscular power of animals.*

(*a.*) Vessels towed by animals. In Leopold's 'Theatrum' is a sketch of a man in a boat holding a plough drawn by horses in shallow water. Barges were until lately drawn on the river Cam by horses walking in the centre of the stream.

I. Three Egyptian paintings represent (not clearly) an ox harnessed to oars.

II. Propulsion by forcing jets of water was patented twenty times before A.D. 1830, although Dr. Allen had proposed to apply the steam-engine thus a hundred years before.

III. Other useless plans employed gunpowder, clockwork, kites or windmills, and one (A.D. 1827) had a drum packed with sponges, which were to move by the weight of water lifted on one side by capillary attraction, and squeezed out at the other by a lever||.

IV. Omitting chapelets and endless chains, of which innumerable applications were made, we may notice the more practical use of *Paddle-wheels.* They are wrongly supposed to have been used in Egypt and Nineveh, and to have been depicted by Vitruvius¶; but they are shown in R. Valturius (A.D. 1472) and Pancirollus (A.D. 1587).

A Chinese drawing of a paddle-wheel vessel is perhaps 600 years old**.

English patents on the subject prepared by the author of this paper, and published by Her Majesty's Commissioners of Patents. It will be hereafter referred to by the letters M. P.)

* See M. P., p. 2. † M. P., p. 2, note.

‡ These descriptions can scarcely be made intelligible without the drawings that accompanied them.

§ Selden, Mar Claus., fol. 258.

|| M. P., p. 85. About 900 patents have been granted in Great Britain for inventions relating to the propulsion of ships.

¶ M. P., p. 7, note (d). ** M. P., p. 5.

The Spaniards assert that Blasco de Garay used a paddle-wheel steam-boat in A.D. 1543‡.

The French account of the Marquis de Jouffroy as the inventor of steam-boats (in A.D. 1783) seems untrue§.

Denis Papin first suggested a paddle-wheel steam-boat (A.D. 1690), then Savery in A.D. 1702, and Hulls in A.D. 1736.

Miller (A.D. 1788), Symington and Taylor made the first practical steam-boat in Scotland.

V. (Omitting notice of countless modifications of vanes and duck-feet propellers.)

Screw propellers were used in China¶, and proposed to be driven by steam, by D. Papin (A.D. 1690) and Bernouilli (A.D. 1752).

VI. Submarine vessels. Alexander the Great used one‖. Van Drebbel made one for King James I., and tried it in the Thames with twelve rowers.

Borelli (A.D. 1683) proposed a submarine metal bag covering a man's head and containing air to breathe. A piston moved in a cylinder (carried round his waist), and lowered or raised him in the water like the natatory organ of a fish. Borelli described also a submarine boat. Bags open to the water could be pressed or extended so as to raise or lower the vessel**.

Williams (A.D. 1692) patented a plan by which men in a tube open to the air above, worked below water with their hands through water-tight sleeves, and similar means had been suggested by drawings in Vegetius††. Diving-bell first noticed in Europe by Taisnier (A.D. 1500).

VII. Steering apparatus and the compass.

One oar was used in Babylonia, and two, three or more in Egypt, all on the same side of the stem.

Several Egyptian paintings represent a steersman sitting between two oars moved by cords; but though two models in the British Museum (unique and well preserved) are furnished with this apparatus, it is difficult to see how it operated ‡‡.

Three rudders (one in the middle) were used in Siam §§.

A ring or enclosed rowlock for hanging the rudder is depicted once on the Egyptian tombs (Lepsius, band 3, bl. 28).

The rudder was first hung on pintles in A.D. 1328¶¶.

A rudder slung by a pole is sketched in an old Japanese dictionary‖‖, and was used 500 years ago by the Danes***.

A tiller is shown in one Egyptian painting (Lepsius, band 2, bl. 101).

Columbus used a vessel steered by oars at opposite ends (as whale-boats are at present).

Rafts on the Rhine are steered by a bough of a tree.

"Starboard" means "styr bord," the side on which hung the "styr" or steer-oar.

R. Valturius (A.D. 1472) says Pericles first used the oar to steer at the stern.

The mariner's compass was probably invented in China†††. It is supposed to be alluded to by Chaucer, and was invented by Gioia of Amalphi, about A.D. 1300. The Arabs used eighteen points for the compass.

Before the use of the loadstone, sailors sent out birds to find the position and distance of the land. Three ravens for this purpose are mentioned in the voyage of Floeo,

‡ Since the above paper was read, the writer has inspected the letters of Blasco de Garay, in the Royal Archives at Simancas in Spain. In these letters there is no mention of the use of steam in the experiments with vessels. After diligent public and private inquiries and search in the libraries and museum of Barcelona, it appears that no valid grounds can be assigned for the assertion that Blasco de Garay invented the steam-boat.

The writer has also inspected a paper at the Patent Office in Paris, duly stamped and signed by notaries, which affirms that the Marquis de Jouffroy caused a vessel 130 feet long to move by a steam-engine on the Saone, in July, A.D. 1783.

§ Discussed minutely in M. P., pp. 33, 34.

¶ M. P., p. 25. ‖ M. P., p. 9. ** M. P., pp. 15, 16.

†† M. P., p. 17. ‡‡ M. P., p. 8 (note.)

§§ Montfaucon's L'Antiquité, &c., vol. ii. p. 82 (quoting Crescentius).

¶¶ Steinitz' ship, p. 122.

‖‖ British Museum. *** M. P., p. 8 (note).

††† For authorities, see M. P., p. 4, note (a).

a Norwegian (Steinitz, p. 41); and the birds sent forth by Noah are thus recalled to notice.

The foregoing paper was further illustrated by an original sketch of a Nile boat made by a Mahommedan, which strikingly resembled the "Heaven-bound ship" depicted by Clemens as a symbol of the "Christian church." Also by an old sketch from the Roman catacombs, in which Noah's ark is shown as a chest with a man in it, and a lock and key. Also by a modern drawing of a steam-boat by a Chinese painter, which contrasted with a sketch of the 'Great Eastern' steam-ship.

On a new Railway Signal. By Dr. Gray.

The author said the new railway-signal had been tested very satisfactorily upon the Midland Great Western Railway. The qualities which it possessed, and which were relied on as establishing its value and efficiency, were,—First, the signal could be made from the guard to the driver and back again with certainty and rapidity. Secondly, that the guard and driver should be able to communicate with each other by means of a code of signals. Thirdly, that in certain cases the signal apparatus should be self-acting automatic; for instance, if any accident caused the severance of the train, which would prevent any communication between the guard and the driver by the voluntary action of either, that notice of the fact would be conveyed to them by the apparatus itself. Fourthly, that there should be no special skill required in order to manage or make the signal; what he meant by that was, that it should not be liable to derangement, and that in case some derangement did occur, the ordinary workmen employed on railway works would be able to set the apparatus right or make a new one. Fifthly, that there should be always a constant indication before the parties in charge of the train that the signal was in working order, so that the guard would not start from the station without knowing that the signal was all right and in reliable condition, and would not fail him upon the journey. The sixth requisite was, that the communication between the carriages should be of such a nature that there would be no serious delay in making up the train of carriages, because of the use of the signal.

The author entered at some length into the principles and details of the invention, and exhibited a working model, the size of the actual apparatus, and several experiments were then tried, all of which worked successfully.

The essential principle of the signal was stated to be the producing, in a metal tube of about $\frac{5}{8}$ inch bore, and which was placed along the entire train of carriages, a more or less perfect *exhaust*, and causing the distribution of that exhaust to act on the signals. A common exhaust-pump, worked by an excentric on the axle of the guard's van, works the pump when the train moves, and instantly exhausts the air from the tube. This action causes a piston-head that plays in a little cylinder at the end of the long tube which is placed in front of the driver, to be pressed up into the cylinder by the external air, and to carry with it and out of view, a red bar or semaphore. This bar remains invisible when all is right, but the guard, by turning a cock on his end of the tube like a gas-cock, destroys the exhaust and lets down the red bar or danger signal in front of the driver's eye. The semaphore is so adjusted, that it is in fact also a weighted lever on a little steam cock to which a whistle is fitted, and when it is let down to indicate danger, it turns on steam by its falling, and so attracts the driver's attention by the whistle. The tube from carriage to carriage has a flexible pendent and a telescope air-tight connexion. This allows freedom of motion, and on the severance of a train the tube is opened, and all the signals given at both ends of the train. Similar signals, the steam whistle alone excepted, are placed in the guard's van, and the driver or any passenger can communicate with him by opening a stop-cock. A little treddle placed near the guard's foot enables him to test the apparatus, and ascertain if the connexions are all right before the train moves. The excentric then maintains the exhaust.

The signals were made through a tube 168 feet in length with the greatest rapidity, and the air was exhausted at one end by an air-pump, but by a simple turning of the cock the effect of this exhaustion was destroyed, and a red bar or semaphore was thrown across a little box representing the box beside the driver, and a whistle was also made to sound by the same instrumentality.

On the Construction of the 36-inch Mortars made by order of Her Majesty's Government. By R. Mallet.

The author gave a verbal account of the two 36-inch wrought-iron mortars, and of the 36-inch shells constructed from his designs for the British Government. He described the peculiarities of their construction, to avoid difficulties of manufacture and of transport in service; and contrasted the powers of demolition as against fortified places, of these large shells, or transferable mines, with the 13-inch shell, the largest heretofore in use, concluding with some remarks on the application of wrought iron to artillery.

On Tangent-Wheels. By Guildford L. Molesworth.

The author first presented some general views in hydraulics, and compared the efficiency of water-wheels, turbines and tangent-wheels. He then described and showed diagrams of a small wheel somewhat similar to the tangent-wheel, for a small workshop.

A description was then given of a tangent-wheel sent by the author to Tasmania for driving a corn-mill of six pairs of stones, with the dressing machinery. The fall was 270 feet, with an available quantity of $2\frac{1}{2}$ cubic feet of water per second. The water was confined in a pipe and brought down to act on the periphery of a wheel 3 feet in diameter, which revolved at a velocity of 360 revolutions per minute; the rims of the wheel were turned up truly on the shaft, and the edges of the inlet carefully faced to correspond with them; the buckets were of wrought iron, cast into the rims, curved and ventilated; the conditions to be observed in forming the curve of the buckets were described as requiring the water to enter without shock, remaining in the bucket sufficiently long to expend its vis viva, and then leaving it without diminishing the effect; the formation of these curves being the most important feature in producing an efficient machine.

The toe of the shaft was so arranged as not to be submerged, and the oiling was managed by a convenient apparatus.

The mechanical effect of the tangent-wheel was stated to be from seventy-five to eighty per cent., which was rather higher than that of Fourneyron's turbine.

Some experimenters had affirmed that Fourneyron's turbines had given out as much as eighty-five or ninety per cent., but it was evident that such statements must arise from some mistake; the consumption of power from different causes was stated to be about twenty-five per cent., leaving only seventy-five per cent. available; the probable source of error was supposed to have arisen from the use of incorrect coefficients for efflux in gauging the amount of water passing through the turbine and probably in some instances from neglecting the element of velocity in the body of water gauged. Castel's formula of $Q=3{\cdot}5\ LH\ \sqrt{H+{\cdot}035\ v^2}$ was given as applicable to the case.

It was also stated, that in practice Whitelaw's turbines gave much less mechanical effect than that usually attributed to them, viz. seventy-five per cent. The causes of loss of power were enumerated, and it was said that many which had been erected on the Continent had given great dissatisfaction, and had been for the most part replaced either by water-wheels, tangent-wheels, or turbines of a different kind. The tangent-wheel had, on the contrary, replaced well-constructed over-shot wheels, and had been highly approved of.

The advantages of the tangent-wheel were summed up as follows:—1st. The water deviated less from its course and was less broken up than in turbines. 2ndly. The tangent-wheel was capable of such regulation as to work with varying quantities of water with undiminished effect, one quarter of the maximum quantity of water producing as good a proportional effect as the maximum. 3rdly. It was cheap and simple, and required no expensive foundations. 4thly. The toe of the shaft was not submerged in the tail-water. 5thly. The working parts were easily got at, and the wheel taken out in a few minutes for examination or repair. 6thly. The velocity of the wheel was not dependent on the quantity of water. 7thly. The motion was extremely steady and regular.

The method of placing the wheel with its axis horizontal was stated to have been tried, but without success, owing to the difficulty of freeing it of water.

In conclusion, it was urged that the tangent-wheel was applicable to many falls in which the adoption of the water-wheel was not only unsuitable but impracticable; and that much water-power which was at present wasted, might be utilized by means of it. It was applicable to all kinds of work, and might be used for agricultural purposes with great advantage.

On the Want of Facts respecting the Performance of Vessels at Sea. By Admiral Moorsom.

The author had himself arrived at results both in speed and in power for a great variety of types which appeared very near the truth; and if a similar method of investigation were applied to carry out experiments conducted at sea under a vast variety of conditions as to form, size, and circumstances, rules might be established which would serve to determine much of what was now the subject of controversy, and go far to remove the reproach on the greatest maritime nation of the world, which was contained in the following passage of a work by Mr. Scott Russell:—"It is admitted that out of every three steam-vessels that are built, two fell very far short of fulfilling the intention with which they were constructed."

Improvements in the mode of Working Steam-Engines. By T. Moy.

By drawings the author showed how he proposed to work steam-engines. No. 1 was an elevation plan and cross section of a pipe-boiler. The boiler is composed of a continuous tube, which may be arranged as in the drawing or in any other efficient mode, and is always kept full of water. By the circulation of the water, the cylinder is always kept at the same heat as the boiler. The heated water circulates through the boiler, jacket, and valve-box of the cylinder; the upper and hottest end of the tube communicates with the upper part of the jacket, and the lower end of the tube carries the cooled water back to the boiler. An open communication is maintained in any convenient place or places between the jacket and valve-box. The slide-valve (Drawing No. 2) has three cavities in it. The upper and lower cavities are for receiving and delivering the necessary quantity of water from the valve-box to the steam-passage. The middle cavity is for the eduction. Before the water-cavity of the valve arrives with its supply of water at the steam-port, its communication with the valve-box is cut off, and this portion of water turns into steam and works the piston. In the drawing No. 2, the upper water-cavity is shown as having arrived opposite the upper passage and the piston has just commenced the down-stroke, while the used steam under the piston is passing off through the eduction. The throttle-valve and regulator must be on the eduction.

The author mentions a plan for controlling the number of inches of water supplied to the cylinder at each stroke without stopping the engine. The engine always works expansively.

Suppose an engine, the internal capacity of whose cylinder is equal to 3 cubic feet, to be supplied by the valve with 3 cubic inches of water at 500° Fahr. As soon as this is at liberty to enter the cylinder it begins to turn into steam, which will drive the piston until all the water has turned into steam; from this point of the stroke to the end the steam will work expansively, and at the end of the stroke will be just equal to the pressure of the atmosphere. By its then passing through the eduction into a surface condenser (without injection, and without attempting to obtain a vacuum), it can be condensed to water and returned to the boiler.

Suppose this engine to be used in a factory. If it is required to reduce the power of the engine in consequence of some of the work being thrown out of gear, this may be done in two ways—by reducing the temperature of the boiler, or by reducing the quantity of water supplied by the water-cavity of the slide-valve; in the former case the engine will work less expansively and with less pressure; in the latter more expansively and with the same pressure at the first portion of the stroke.

By this mode of working steam-engines, great safety with increased pressure and compactness may be obtained; incrustation of the boiler and priming of the cylinder will be prevented.

On the Philosophy of the Wave-Line System of Ship-building. By T. Moy.

The purport of this paper was to explain the mode of forming the wave-line; the reason why the wave-line is the best form for vessels; and to show how speeds equal to fifty miles an hour and upwards may be attained by using the wave form in its integrity.

The mode of forming the wave-line was shown in the drawing exhibited.

Treating water as subject to the same laws as solid bodies in motion, it was urged that the best motion for one atom of the column of water in travelling its 20 feet from the cutwater to the extent of the midship section, is that which the piston of a steam-engine would receive if connected with a crank of the length of 10 feet, the connecting rod being supposed to be infinite. The wave-curve imparts this motion to each atom, and therefore to the whole column of water; and any attempt to make this line either fuller or sharper will cause a decrease of speed. Also that any angle whatever formed at the stem with the line of motion is improper and highly detrimental to speed.

It was proposed that the common term "resistance" is inapplicable, and that the term "duty" is preferable.

The subject was then illustrated by supposing a vessel of 40 feet beam, 100 feet length of bow, and 200 horse power to travel at ten miles an hour; this vessel's *duty* would be that of giving motion to two columns of water, one on each side of her keel at right angles to her course, at a speed of 176 feet per minute or 2 miles an hour. This vessel was called No. 2. No. 3, with a bow 200 feet long, the same midship section, and 400 horse power, will perform the duty of putting the water in motion at 176 feet per minute or 2 miles an hour, while she performs 20 miles an hour. No. 4, with 250 feet bow and the same midship section and 500 horse power, will put the water in motion at the same speed, 176 feet per minute or 2 miles an hour, while the vessel performs 25 miles an hour; and No. 5, with a bow 500 feet long and the same midship section, performs the same duty of putting the water in motion at the same low speed of 2 miles an hour, while she travels at the speed of 50 miles an hour, and only requires 1000 horse power,—while the 'Great Eastern,' in consequence of her great beam, would have to give motion to the column of water equal to $6\frac{1}{3}$rd miles an hour, in order to attain a speed of 50 miles an hour. A vessel of 8000 tons and 1000 horse power could be built upon the above sharp lines to travel at the rate of 50 miles an hour.

The following is the rule to find the speed of the water at right angles to the line of motion:—Divide the speed in feet per minute by the length of bow and multiply the product by half the length of beam, which gives the speed of the column of water in feet per minute. The following Table was referred to:—

No.	Length of bow.	Speed per minute in ft.	Miles per hour.	Speed of column of water per minute.
1.	20 feet	176	2	176 feet
2.	100 ,,	880	10	176 ,,
3.	200 ,,	1760	20	176 ,,
4.	250 ,,	2200	25	176 ,,
5.	500 ,,	4400	50	176 ,,
'Great Eastern.'	330 ,,	4400	50	547 ,,

On the Laying of Submarine Telegraph Cables. By Sir J. Murray.

Mr. B. A. Murray made some observations on the advantages of "spinning silk from the cocoon," and exhibited a model of machinery invented and patented by him for effecting the new process; and stated that silk spun in this manner was perfectly even and free from knots, and consequently greatly superior to the article produced by the old system; in addition to which a great saving of labour and machinery was effected; weft being produced in one operation, and organgine in two operations, from the cocoon. One speciality of the patent is the spinning of the skeining reel and bobbin*.

* Applied to raw silk, the machine in one operation spins, doubles, and throws silk wound to a bobbin from the skein.

Some Facts on the Flow of Water through Circular Pipes. *By* J. Neville.

On the Submarine Electric Telegraph Cable. *By* A. Balestrini.

On the Principle of the Transformation of Structures. *By* W. J. Macquorn Rankine, *LL.D., F.R.S. L. and E.*

This paper consists of an explanation of some of the practical applications of a principle first communicated by the author to the Royal Society in 1856, viz.—*if a structure of a given figure be stable under a system of forces represented by given lines, every structure whose figure is a parallel projection of the given figure is stable under a system of forces represented by the corresponding parallel projections of the given lines.*

(Two figures are said to be *parallel projections* of each other when every pair of parallel and equal lines in one figure corresponds to a pair of parallel and equal lines in the other. Thus all circles and ellipses are parallel projections of each other; so also are all spheres and ellipsoids.)

This principle enables the design for a bridge with a sloping extrados and a distorted semi-elliptical arch to be deduced from the design for a bridge with a horizontal extrados and a semicircular arch. In like manner, from the figure of an equilibrated arch for sustaining the pressure of a fluid, which is equal horizontally and vertically, can be deduced the figure of an equilibrated arch for sustaining the pressure of earth, which is less horizontally than vertically in a given ratio; and various analogous problems can be solved with ease by the principle of the transformation of structures, whose solution by a direct process would be very tedious and difficult.

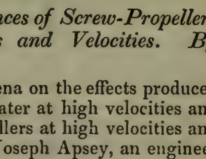
Continuation of Experiments to determine the Resistances of Screw-Propellers when revolving in Water at different Depths and Velocities. *By* George Rennie, *F.R.S., &c.*

My former experiments exhibited some curious phenomena on the effects produced on the resistances of screw-propellers when revolving in water at high velocities and at different depths. The first idea of driving screw propellers at high velocities and immersed at different depths was stated to be due to Mr. Joseph Apsey, an engineer of Broad Wall, in the parish of Christ Church, Surrey, but from the experiments having been made in a close boiler, objections were made to them at Glasgow as being fallacious; and it was only after similar experiments had been made by me in the open water in the river Thames that they were confirmed. Those results were given in my last paper, published in the 'Transactions of the British Association' in 1856.

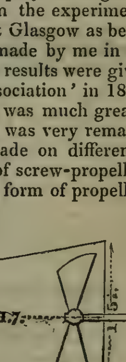
Both series of experiments proved that the influence of velocity was much greater than that of depth, but that the joint action of velocity and depth was very remarkable. The present paper contains the results of experiments made on differently formed propellers, for the purpose of ascertaining, first, the effects of screw-propellers when confined in tubes of a conical form; secondly, the effects of form of propellers working alone and not in tubes.

The common two-bladed screw, 13 inches diameter, pitch 20 inches, 600 revolutions per minute, when working in a depth of 12 inches above top of screw, gave a pressure of 69 lbs. in a conical tube

	ft.	in.	
of 69 lbs. in a conical tube	1	5½	diameter, large end.
	1	2¾	,, small end.
	1	7	in length.



The same two-bladed screw, when immersed and working in a depth of 12 inches above top of screw, gave a pressure of 144 lbs., or more than double of the pressure when confined by the tube.



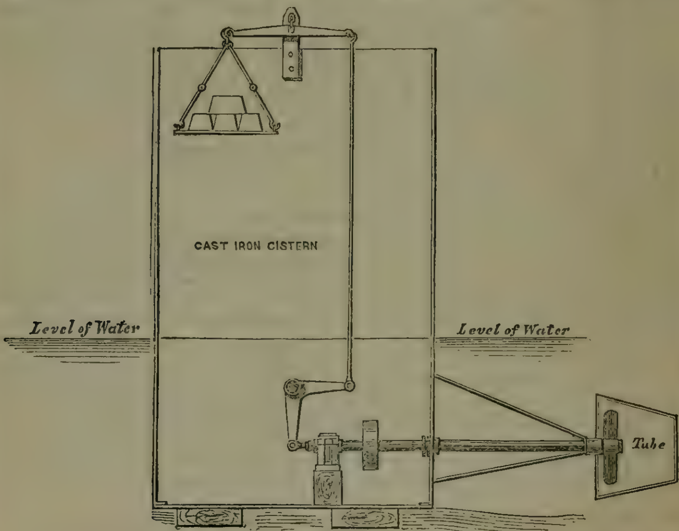
Without working in a tube.—Effects produced by a three-bladed screw-propeller of similar diameter, 13¼ inches and pitch 20 inches, area of circle 1 square foot to the two-bladed screw and moved at the same velocity of 600 revolutions per minute, and immersion of 12 inches above the level of the screw without a tube,—157 lbs.

Without working in a tube.—Effects produced by a two-bladed screw-propeller, similar to the common screw, in diameter $13\frac{1}{2}$ inches and 20 inches pitch, area 1 square foot, but having a portion of the interior of its blades cut away in hollow curves,—176 lbs.

Without working in a tube.—Effects produced by a two-bladed screw-propeller, $13\frac{1}{2}$ inches diameter and 20 inches pitch, but tapered at the outer extremities of the blades in a parabolical form thus :—137 lbs. Area of circle 1 square foot.

The above experiments were varied in many ways both in speed and depth; but the mean pressures which are given are sufficiently approximate. The greatest result is given by the curved-bladed propeller.

Apparatus for trying the resistances of different Screws when immersed at similar depths in the River Thames.



On the Quantity of Heat developed by Water when rapidly agitated. By George Rennie, *F.R.S.*

My last paper, communicated to the Mechanical Section of the British Association at Cheltenham, in August 1856, contained a brief notice of the experiments which had been made upon this subject by Count Rumford, and by Mayer, Joule, Thomson, Rankine, &c. The mechanical equivalents which were estimated by those philosophers therefrom, and the heat developed by chemical as well as by mechanical action, were briefly noticed; and the causes which led to the making the experiments were shown to have originated in the development of heat observed by me in the sea in stormy weather, and when water ran through sluices at Southampton Dock and other confined apertures. As formerly stated, the experiments were made by agitating rapidly a mass of 437 lbs. of well-water confined in a cubical box, until its temperature became elevated from 59° Fahrenheit's thermometer to $103\frac{1}{2}$° by the same

scale, but without adding the loss of heat by the radiation of the mass; thus proving the correctness of the theory, namely, that water, like other fluids, was subject to the same laws as govern chemical or mechanical action; and that friction or agitation was neither more nor less than a disturbance of molecular equilibrium, which, by deranging from their natural positions the particles of bodies, developes heat and electricity, according to the constitution of the bodies subject to their action, and to the rapidity with which those operations were performed. Encouraged therefore by the facts elicited by the experiments of last year, I undertook this year a new series of experiments, the objects of which were,—

1st. To prove the accuracy or not of the last year's experiments.

2nd. The law, or approximation to it, of increased temperature.

3rd. The possibility of attaining the boiling-point.

4th. The mechanical equivalent of heat to mechanical power.

For these purposes an entirely new apparatus was prepared. It was driven by the steam-engine as before.

Description of the Apparatus for Churning Water.

The apparatus consisted in the first new series of experiments of a cubical deal box, 28 inches square and 23 inches in depth. It was covered with a lid of the same material, fitted to prevent the water from escaping while in motion, and was perforated with a circular hole in the middle of the lid, to allow the working freely of a vertical axis or spindle. The spindle itself, which was $2\frac{3}{4}$ inches square, was furnished with eight radial arms, fitted with a series of vertical stirrers nailed upon their sides, to break the water as much as possible; and to prevent rotary motion in the water, vertical boards were fixed in the corners of the box. The axle was supported in two bearings above the box, and had no bottom spindle as in the former experiments, an objection which was urged last year. On the contrary, the bottom of the vertical axis was 3 inches above the bottom of the box. It is clear, therefore, whatever heat might have been generated by the friction of the bearings of the vertical axle could not be communicated to the water, and such was found to be the case. The whole apparatus was of wood.

The box, when filled, contained 50 gallons or 500 pounds of well-water, previous to the apparatus being set in motion on the 19th of June, 1857; the following were the results of a preliminary trial:—

Third Series of Experiments.—*June* 19, 1857.

Result of first day (9 *hours*), *heating water by churning.*

Time. h m	Temp. of water in box. °	Temp. of air. °	Time. h m	Temp. of water in box. °	Temp. of air. °
11 30 A.M.	61·0	70	4 30 P.M.	68	
12 30 P.M.	60·5		5 30 „	69·5	
1 30 „	62·5		6 30 „	71	
2 30 „	64	72	7 30 „	72	
3 30 „	66		8 30 „	73	70

Temperature of water in box increased from 60°·5 to 73°. Increase in 9 hours 13°·5

Loss by radiation in $10\frac{1}{2}$ hours 9°=85°·7 per hour. 9 hours at 85°·7 per hour 7°·7

Total increase in 9 hours 21°·2 or 2°·35 per hour. Total increase 21°·2

Average revolutions per minute 88·64.

50 gallons of water at starting. 42·5 gallons of water at stopping.

Third Series of Experiments.—*June* 20, 1857.

Result of second day (9 *hours*), *heating water by churning.*

Time. h m	Temp. of water in box. °	Temp. of air. °	Time. h m	Temp. of water in box. °	Temp. of air. °
7 0 A.M.	64	66	12 0 P.M.	81	
8 0 „	67		1 0 „	84·5	74
9 0 „	69		2 0 „	88	
10 0 „	72		3 0 „	90	
11 0 „	77·5		4 0 „	92	74

Temperature of water in box increased from 64° to 92°. Increase in 9 hours 28°
Loss by radiation 1° per hour. 9 hours at 1° per hour . . . . 9°

Total increase 37°

Total increase of temperature in 9 hours 37°, or 4°·1 per hour.
Average number of revolutions 88·64.
50 gallons of water.

Third Series of Experiments.—*June* 22, 1857.

Result of third day (8 *hours*), *heating water by churning.*

Time. h m	Temp. of water in box.	Temp. of air.	
9 30 A.M.	56°	61°	Began with cold water, in consequence of plug in bottom of box leaking.
10 30 „	58		
11 30 „	61		
12 30 P.M.	63·5		
1 30 „	68	66	10 30 A.M. Stopped 15 minutes in consequence of belt breaking.
2 30 „	74		
3 30 „	76		2 15 P.M. Gauge-glass broke.
4 30 „	80		
5 30 „	83	68	

Temperature of water in box increased from 56° to 83°. Increase in 8 hours 27°
Loss from radiation in 13 hours 13°, or 1° per hour. 8 hours at 1° per hour. 8°

Total increase 35°

Total increase of temperature in 8 hours 35°, or 4°·375 per hour.
Average revolutions per minute 88·64.
50 gallons of water at starting. 45 gallons of water at stopping.

Third Series of Experiments.—*June* 24, 1857.

Result of fourth day (11 *hours*), *heating water by churning.*

Time. h m	Temp. of water in box.	Temp. of air.	Time. h m	Temp. of water in box.	Temp. of air.
6 30 A.M.	72°	64°	1 30 P.M.	98°	
7 30 „	79		2 30 „	100	
8 30 „	84		3 30 „	101	
9 30 „	87		Stopped 20 minutes, broke belt.		
10 30 „	90		4 30 P.M.	102	
11 30 „	93		5 30 „	104	75
12 30 P.M.	96	74			

Temperature of water in box increased from 72° to 104°. Increase in 11 hours 32°
Loss by radiation in 13 hrs. 2°, or ·0153° per hour. 11 hours at ·0153° per hour 1°·6

Total increase 33°·6

Total increase of temperature in 11 hours 33°·6, or 3°·05 per hour.
Average revolutions per minute 88·64.
50 gallons of water.

Third Series of Experiments.—*June* 25, 1857.

Result of fifth day (13 *hours*), *heating water by churning.*

Time. h m	Temp. of water in box.	Temp. of air.	
6 30 A.M.	102°	68°	Box covered with hair-felt on previous night, to prevent radiation as much as possible.
7 30 „	105		
8 30 „	107		

Time. h m	Temp. of water in box.	Temp. of air.	
9 30 A.M.	109°	°	Stopped 15 minutes to tighten first-motion driving belt.
10 30 „	115		
11 30 „	118		
12 30 „	122·5	78	
1 30 P.M.	126		
2 30 „	130		Thermometer indicates no higher.
3 30 „			Stopped 30 minutes to cut larger hole for new thermometer.
4 30 „	132		
5 30 „	134		
6 30 „	136		
7 30 „	140	76	

Temp. of water in box increased from 102° to 140°. Increase in 13 hours 38°
Loss by radiation in 11½ hrs. 18°, or 1°·56 per hour. 13 hrs. at 1°·56 per hour 20°·28

58°·28

Total increase of temperature in 13 hours 58°·28, or 4°·483 per hour.
Average number of revolutions per minute 88·64.
50 gallons of water.

First Series of Experiments.—*June* 26, 1857.

Result of sixth day (13 *hours*), *heating water by churning.*

7 0 A.M.	122	62	7.45 A.M. second-motion belt broke: started again 8 A.M.
8 0 „	124		
9 0 „	128		9 5 A.M. Glass tube in which thermometer was placed broke, carrying thermometer into box; defect made good; started again 10 15 A.M.
10 0 „			
11 0 „			
12 0 P.M.	124		
1 0 „	128	76	
2 0 „	130		
3 0 „	132		
4 0 „	136	78	
5 0 „	138		
6 0 „	140		
7 0 „	142		
8 0 „	144	76	

Temp. of water in box increased from 122° to 144°. Increase in 13 hours . 22°
Loss by radiation in 11 hrs. 18°, or 1°·63 per hour. 13 hrs. at 1°·63 per hour . 20°·19

42°·19

Total increase of temperature in 13 hours 42°·19, or 32°·45 per hour.
Average number of revolutions per minute 88·64.
50 gallons of water.

Second Series of Experiments.—*July* 14, 1857.

Result of seventh day's trial.—Apparatus for heating water in small box.

Temperature of water in box increased from 68° to 118°, or 50° in 5 hours.
Loss from radiation in 13 hours 22°, or 1°·69 per hour, 8°·45 in 5 hours.
Total increase of temperature of water in box 58°·45.
Total increase of temperature of water in 5 hours 58°·45, or 11°·69 per hour.
Five gallons of water in box.
236·04 revolutions per minute.

The churning-box on this trial was entirely covered with hair-felt, and stood upon four glass pillars 2 inches high. This was placed in an outer box; the inner or churning-box being stayed with glass props to prevent radiation by coming in contact with the outer box, or from moisture which might accumulate in bottom of same.

The iron wheel driving churn-spindle (wood) was also covered with worsted cord, this acting as a non-conductor of heat.

SECOND SERIES OF EXPERIMENTS.—*July* 21, 1857.

Result of eighth day's trial of 11 *hours.—Apparatus for heating water.*

Time. h m	Temp. of water in box. °	Temp. of atmosphere. °	Time. h m	Temp. of water in box. °	Temp. of atmosphere. °
6 30 A.M.	103	69	12 30 P.M.	160	76
7 30 „	116	68	1 30 „	164	76
8 30 „	126	69	2 30 „	166	76
9 30 „	136	71	3 30 „	172	77
10 30 „	146	72	4 30 „	173	77
11 30 „	152	74	5 30 „	178	80

12 gallons of water at starting. 6 gallons of water at stopping.

Highest temperature . . . . 178°
Lowest temperature . . . . 103°

236·67 revolutions per minute. 75°

SECOND SERIES OF EXPERIMENTS.—*July* 25, 1857.

Result of ninth day's trial of $11\frac{1}{2}$ *hours.—Apparatus for heating water.*

Time. h m	Temp. of water in box. °	Temp. of building. °
6 30 A.M.	130	70
7 30 „	138	70
8 30 „	148	72
9 30 „	158	72
10 30 „	162	74
11 30 „	170	74
12 30 P.M.	178	76
1 30 „	182	76
2 30 „	184	77
3 30 „	190	76
4 30 „	190	76
5 30 „	192	76
6 30 „	192	76

6 30 A.M. 6 gallons of water in box at a temperature of 130°. Added 4 gallons of water to that in box; temperature when mixed 130°.

$11\frac{1}{2}$ hours at work. 232·67 revolutions per minute.

10 gallons of water at starting. 7·5 gallons of water at stopping.

Highest temperature . . . . 192°
Lowest temperature . . . . 130°

62°

THIRD SERIES OF EXPERIMENTS.—*July* 16, 1857.

Result of tenth day's trial of 11 *hours.—Apparatus for heating water.*

Time. h m	Temp. of water in box. °	Temp. of shop. °	Time. h m	Temp. of water in box. °	Temp. of shop. °
7 0 A.M.	168	68	1 0 P.M.	193	70
8 0 „	172	67	2 0 „	196	70
9 0 „	180	68	3 0 „	200	72
10 0 „	184	68	4 0 „	204	72
11 0 „	188	68	5 0 „	206	72
12 0 „	190	70	6 0 „	209*	72

Temperature of water in box at 6 30 A.M. . . . . 136°
Added 3 gallons of water at temperature of . . . . . 210°
Increasing that already in box to . . . . 168°

* At this temperature an egg was put into the water, and the agitation was continued for five minutes, when the egg was taken out and found boiled quite hard.

90·5 gallons of water at starting. 8 gallons of water at stopping.
232·67 revolutions per minute for $10\frac{1}{2}$ hours.
Increased during last half-hour to 274·67 revolutions.

Highest temperature	209°
Lowest temperature	168°
	41°

General Result of First Series with 50 *gallons or* 500 *lbs. water agitated at* 88·64 *revolutions per minute.*

No. of Experiments.	Duration of Experiments.	Degree, including radiation.		Degree per hour.
1.	Increase in 9 hours	21° 2″	or	2·35 per hour.
2.	,, 9 ,,	37 0	,,	4·10 ,,
3.	,, 8 ,,	35 0	,,	4·37 ,,
4.	,, 11 ,,	33 6	,,	3·05 ,,
5.	,, 13 ,,	58 28	,,	4·48 ,,
6.	,, 11 ,,	42 11	,,	4·21 ,,
				6/22·56

General average increase per hour .... 37·6 Fahr.
Loss by leakage 10 per cent.

General Result of Second Series with 10 *gallons or* 100 *lbs. of water agitated at* 236·67 *revolutions per minute.*

No. of Experiments.	Duration of Experiments.	Degree, increase.		Degree per hour.
1.	Increase in 5 hours	58·45	or	11·69 per hour.
2.	,, 11 ,,	75	,,	6·81 ,,
3.	,, $11\frac{1}{2}$,,	62	,,	5·39 ,,
4.	,, 11 ,,	41	,,	3·72 ,,
				4/27·61
				6·90

Loss by leakage, &c. 10 per cent.

Mechanical Equivalents.

First Series.—These were obtained by means of Prony's Friction Break applied to a correctly turned pulley of cast iron, fitted in the upper part of the vertical wooden spindle of the agitator. The friction bracket was carefully equilibriated on the pulley by means of weights, oil, and tallow until it made the same number of revolutions as before; the box having previously been emptied of its water.

The following were the results:—

1st. That 500 lbs. of water agitated at the rate of 88·64 revolutions per minute were heated 3°·38 per hour by an expenditure of 29·000 lbs. per minute. This is equivalent to 1690 lbs. raised one degree.

Then $29{\cdot}000\times60=\frac{174{\cdot}000}{1690}=1030$, equivalent to 1 lb, being heated 1° in one hour.

Second Series.—That 100 lbs. of water agitated at the rate of 232·67 revolutions per minute were heated 6°·27 per hour by an expenditure of 1·8 H. P., or $59{\cdot}400\times60=356{\cdot}400$ lbs. This is equivalent to 621 lbs. raised 1° in one hour.

From the preceding result it appears that the mechanical equivalent varies as the quantity of water used in the experiment, and the rate of agitation; the larger quantity of water agitated by 88·64 revolutions giving an equivalent of 1030 lbs., and the smaller quantity giving only 621 lbs. when agitated 232·67 revolutions.

Mechanical Structure of the 'Great Eastern' Steam Ship. *By* John Scott Russell, *F.R.S.*

The author laid before the Section some of the mechanical details of the construction of the great ship now building at his establishment at Millwall. The first point related to the peculiarity of her great size; the second, on which her merits or demerits as a piece of naval architecture depended, was the general structure or lines

of the ship; the third point would be the distribution of materials in the construction of the ship, so as to obtain the safest and strongest possible structure with the minimum of materials; and the last point would be to allude generally to the mechanical arrangements for her propulsion. With respect to size, it was generally supposed that, as a practical shipbuilder, he was an advocate for big ships. The contrary, however, was the fact. There were cases in which big ships were good, and there were certain cases in which big ships were ruinous to their owners. In every case the smallest ship that would supply the convenience of trade was the right ship to build. He came there as an advocate of little ships; and it was the peculiarity of the 'Great Eastern' that she was the smallest ship capable of doing the work she was intended to do; and he believed that if she answered the purpose for which she was designed, she would continue to be the smallest ship possible for her voyage. It was found by experience that no steam-ship could be worked profitably which was of less size than a ton to a mile of the voyage she was to perform, carrying her own coal. Thus, a ship intended to ply between England and America would not pay permanently unless she were of 2500 or 3000 tons burden. In like manner, if a vessel were intended to go from this country to Australia or India, without coaling on going out, but taking her coals with her, she would require to be 13,000 tons burden. And turning to the case before them, it would be found that the big ship was a little short of the proper size. Her voyage to Australia and back would be 25,000 miles; her tonnage, therefore, should be 25,000 tons, whereas its actual amount was 22,000 tons. The idea of making a ship large enough to carry her own coals for a voyage to Australia and back again was the idea of a man famous for large ideas—Mr. Brunel. He suggested the matter to him (Mr. Russell) as a practical shipbuilder, and the result was the monster vessel which he was about to describe.

He had peculiar pleasure in laying a description of the lines of the ship before the present meeting, because the ship, as a naval structure, as far as her lines were concerned, was a child of the British Association. It was twenty-two years since they had the pleasure of meeting together in Dublin. On that occasion he laid before the Mechanical Section a form of construction which had since become well known as the "wave-line." The Section received the idea so well that it appointed a committee to examine into the matter, with the intention, if they found the wave principle to be the true principle, to proclaim it to the world. The committee pursued its investigations, publishing the results in the account of their 'Transactions;' and from that time to the present he had continued to make large and small vessels on the wave principle; and the diffusion of the knowledge of this system through the 'Transactions of the British Association' had led to its almost universal adoption. Wherever they found a steam-vessel with a high reputation for speed, economy of fuel, and good qualities at sea, he would undertake to say that they would find that she was constructed on the wave principle.

He would endeavour to explain what were the principles of the wave-line as distinguished from the older-fashioned modes of building, and how they were carried out in the big ship. All practical men knew that the first thing a shipbuilder had to think of was what was called the midship section of the vessel: that was, the section which would be made if the vessel were cut through the middle, and the spectator saw the cut portions. Mr. Russell here pointed out a diagram of the midship section of the 'Wave,' a small vessel about $7\frac{1}{2}$ tons burden, which was the first ever constructed upon that principle. Now the first thing to be done in building a steam-vessel was to make a calculation of the size of the midship section in the water. In sailing from one place to another, it was necessary to excavate a canal out of the water large enough to allow the whole body of the ship to pass through. The problem was, how to do that most economically; and this was effected by making the canal as narrow and as shallow as possible, so that there would be the smallest quantity of water possible to excavate. Therefore it was that the shipbuilder endeavoured to obtain as small a midship section as he could; and that had been effected in the case of the big ship, whose midship section was small,—not small absolutely, but small in proportion.

In increasing the tonnage of a ship, three things had to be considered, the paying power, the propelling power, and the dimensions. Mr. Russell then entered into a

calculation to show that while he doubled the money-earning power of a ship by increasing its size, he only increased its midship section by 50 per cent. For instance, a ship of 2500 tons burden would have 500 feet of excavation through the water to do; the big ship had 2000 feet of excavation; and the lineal dimensions of one were to the lineal dimensions of the other as 1 to 2·1. The excavation to be done by the big ship in relation to that to be done by the small ship was as 4 to 1, but the carrying power was as 10 to 1. To propel the big ship they had a nominal H.P. of 2500, while to propel the smaller vessel there was a nominal H.P. of 500; so that the big ship would be worked quite as economically as the small one.

Referring again to the wave-line, he would suppose that it was given as a problem to any one to design a ship on the wave principle. The first thing to be done was to settle the speed at which the ship was intended to go. If the speed were fixed at 10 miles an hour, a reference to the table of the wave principle would show that, in order to effect that object, the length of the ship's bows ought to be about 60 feet, and that of her stern about 40 feet. If a larger vessel were required, say a ship of 130 feet long, there would be nothing more to do than to put a middle body of 30 feet in length between the bow and the stern. Having then made the width of the ship in accordance with the midship section agreed upon, it would be necessary to draw what was known as the wave-line on both sides of the bow, and the wave-line of the second order on both sides of the stern. Constructed in this manner, and propelled by the ordinary amount of H.P., the ship would sail precisely 10 miles an hour. They could go slower than 10 miles an hour if necessary, and in doing so they would economise fuel, in consequence of the diminished resistance of the water; whereas there would be a vastly increased resistance if an attempt were made to drive the steamer more than 10 miles an hour.

For the speed at which it was intended to drive the 'Great Eastern,' it was found that the length of her bow should be 330 feet, the length of her stern 220 feet, of the middle body 120 feet, and of the screw propeller 10 feet; making in all 680 feet in length. The lines on which she was constructed were neither more nor less than an extended copy of the lines of all the ships which he had built since he first laid the wave principle before the Association. It was his pride that he had not put a single experiment or novelty into the structure of the vessel, with one or two exceptions, which he had adopted on the recommendation of men who had had practical experience of their efficacy. The wave principle had never in a single instance deceived him as to the exact shape a vessel ought to have in order to accomplish a certain rate of speed, and he had therefore adopted it in the construction of the big ship.

He would next refer to the mechanical construction of the big ship, the arrangement of the iron of which she was made, and the object of those arrangements. It was much to be desired that our mechanical science should make progress by the simple adoption of what was best, come from where it might; but he was sorry to say that iron shipbuilding did not grow in that manner. They commenced by servilely imitating the construction of wooden ships, thereby incurring a great deal of unnecessary labour and expense. There was this great difference between the strength of iron and of wood, that whilst the latter was weak crossways and strong lengthways, or with the grain of the timber, iron was almost equally strong either way. This had been clearly ascertained by experiments made by Mr. Fairbairn and Mr. E. Hodgkinson, at the request of the British Association, in whose 'Transactions' the results were published to the world. The consequence was, that the ribs or frames used to strengthen wooden ships were rendered unnecessary in iron shipbuilding; and acting on this principle, the 'Wave' (in the construction of which he was assisted by two Irishmen) was built of iron entirely, with bulkheads, and had not a frame in her from one end to the other. He was ashamed to say he did not always practise what he preached. He was compelled against his will, by the persons for whom he built, to pursue the old system; besides which, there were laws of trade, Acts of Parliament, and Lloyd's rule, to which he was obliged to conform. Thus, if he did not put a certain number of frames in the ship, a black mark would be put upon her, and she would not be allowed to go to sea. But whenever he was allowed to build according to his judgment, he built in what he considered to be the best way. And he believed that in what he was now placing

before the Section he was laying the grounds of meeting the British Association that day twenty years, and finding that the mode of mechanical construction which he proposed had been as universally adopted as the wave principle, because of the publications of the British Association.

The author then proceeded to give an elaborate description of the old method of constructing an iron ship, contrasting it with the improved style which he pursued at present. Instead of the mass of wooden rubbish, which did not strengthen the ship, and involved enormous expense, he placed inside the iron shell as many complete bulkheads as the owner permitted him to do, and then constructed in the intermediate spaces partial bulkheads, or bulkheads in the centre of which holes had been cut for the purposes of stowage. The deck was strengthened by introducing pieces of angle iron, and other contrivances; and as an iron ship when weak was not weak crossways, but lengthways, he strengthened it in this direction by means of two longitudinal bulkheads; and the result was a strength and solidity which could not be obtained in any other way. The 'Great Eastern' had all these improvements, and, in addition, the cellular system, so successfully applied in the Britannia Bridge, had been introduced all round the bottom and under the deck of the ship, giving the greatest amount of strength to resist crushing that could be procured. As he had already observed, there was nothing new in the ship but her great size and cellular construction. It was true she would be propelled both by screw and paddles, but there was no reason to doubt that they would work harmoniously. He wished he could tell them how fast she would go, but that was the secret of the owners of the ship.

On the Importance of Regulating the Speed of Marine Engines. *By* T. Silver.

On the Formation of the Entrances to Tidal Basins. *By* Bindon B. Stoney, *M.R.I.A.*

In the formation of the entrances to tidal basins, two points have to be considered:

1. The shape of the entrance.
2. Its position.

In existing docks we find some entrances constructed at right angles to the river, others sloping upwards against the stream, and others again sloping downwards, which latter form not only tends to prevent deposits, but greatly facilitates the entrance and departure of vessels. Even though no downward current does exist in the river, that form of entrance which slopes in the direction of the vessel's course presents obvious advantages, especially in the case of a narrow river, where it is essential that a ship should, both before entering and after leaving the basin, be in the line of the river, and at the same time not far from its centre, where the channel is deep and unobstructed.

The usual position of the entrance is at or near the centre of that side of the basin which is parallel to the river. This however is objectionable, since, besides promoting deposit, it makes it necessary that vessels lying within the basin be warped, at no small expense of time and labour, into a suitable position for passing through.

The chief considerations to be kept in view in the construction of floating docks or tidal basins are as follows:—

1. Facility of ingress and egress.
2. Freedom from silting up.

To these may be added,—

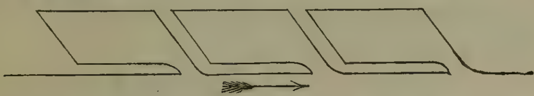
3. Economy of quay room.
4. Facilities for the land traffic in connexion with the dock.

These conditions are, it is believed, in a great measure fulfilled by the form of entrance advocated by the author. The general form of the basin is a lozenge, a trapezium, or a rectangle, whose width is equal to the breadth of two vessels together, with sufficient space between them for another vessel to turn round freely: the entrance, placed at the lower end, is well sloped in the direction of the ebb current, and has its

obtuse angles rounded off, so that a ship or steamer can pass from the river into the basin, and take up her berth without warping, or any such annoyance and delay.

Similarly, on leaving, a vessel, when once her head is round, can pass out without slacking speed, and therefore without risk of being carried by the current against the pier-heads. The diagram represents a succession of basins formed according to the proposed method, and, if desirable, at different periods to meet the exigencies of the port, yet in such a manner that there is easy communication between each quay and the main road leading into the city or the traffic depôts. These quays are, from the obtuse angles at which they intersect, well adapted for tramways, which may branch off a trunk line laid along the main road.

When additional port accommodation is thus obtained the result cannot but be beneficial to the river, since these basins will act as reservoirs, increasing the volume of water which passes through the channel, and thus aiding by its source in maintaining the river at its proper depth.



On Machinery for Laying Submarine Telegraph Cables. *By* Professor W. Thomson.

On Superheated Steam. *By* J. Wetherhead, *United States.*

APPENDIX.

On the proposed Ship Canal through the Isthmus of Suez. *By* Dr. Hodgkin.

Although the difficulty at one time supposed to exist in the difference of level between the Mediterranean and Red Seas is now no longer urged, there are other physical difficulties which are of at least equal importance. The canal must not only be made, but must also be maintained in a serviceable condition. Now, it is well known that on the Mediterranean side the sea is not only shallow and sandy, but that its depth is subject to constant variation from the moving character of the sand-banks. It might almost be presumed, *à priori*, that the same causes which prevent any of the mouths of the Nile from serving as an available ingress or egress for vessels navigating the Nile, would produce and maintain an effectual obstacle to vessels passing in either direction between the Mediterranean Sea and an artificial canal. I had an opportunity of witnessing a strong confirmation of this inference in proceeding from Alexandria to Jaffa. Although we kept out at sea to the distance of some miles, the captain of the steam-boat, which was a much smaller vessel than would be required for Indian or Australian commerce, thought it needful, in broad daylight, to be frequently using the sounding-line as a security against stranding his vessel. The force of this objection is so far admitted by the advocates of the canal as to induce them to allow that it will be necessary to construct piers advancing some miles into the sea, and that at their mouth, and in the channel between them, it will be requisite to keep dredging vessels constantly employed to preserve a practicable passage.

It will, perhaps, be asked in what the difficulties consist? The general facts may be safely stated to be—first, a certain amount of elevated land to be cut through; secondly, land considerably lower than either sea, where very substantial embankments must be thrown up to prevent the neighbouring country from being submerged. Throughout this tract, and probably along the greater portion of the line, a very careful and expensive process of puddling will be absolutely necessary to enable the canal to hold water.

INDEX I.

TO

REPORTS ON THE STATE OF SCIENCE.

INDEX II.

TO

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

LIST OF PLATES.

PLATE I.

PLATE II.

PLATE III.

PLATE IV.

PLATE V.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The Published Reports of Proceedings at the Meetings of the Association may be obtained by *Members* on application to the under-mentioned Local Treasurers, or Agents appointed by them, at the following prices, viz.—Reports for 1849, 1850, 1851, 1852, 1853, 1854, 1855, 1856, 1857, at two-thirds of the Publication Price; and for the purpose of completing their sets, any of the first seventeen volumes, *of which more than* 100 *copies remain*, at one-third of the Publication Price.

	TREASURER.	DEPOT FOR THE REPORTS.
LONDON	John Taylor, Esq., F.R.S. 6 Queen Street Place, Upper Thames Street.	Messrs. Taylor & Francis, Printing Office, Red Lion Court, Fleet Street.

	LOCAL TREASURERS.	DEPOTS.
YORK	William Gray, Esq., F.G.S.	Yorkshire Museum.
CAMBRIDGE	C. C. Babington, Esq., M.A., F.R.S.	House of the Philosophical Society.
EDINBURGH	William Brand, Esq.	Union Bank of Scotland.
DUBLIN	John H. Orpen, LL.D.	13 South Frederick Street.
BRISTOL	William Sanders, Esq., F.G.S.	Philosophical Institution, Park Street.
LIVERPOOL	Robert McAndrew, Esq., F.R.S.	7 North John Street.
BIRMINGHAM	W. R. Wills, Esq.	Birmingham.
GLASGOW	Professor Ramsay, M.A.	The College.
MANCHESTER	R. P. Greg, Esq., F.G.S.	Chancery Lane.
SWANSEA	John Gwyn Jeffreys, Esq., F.R.S.	Swansea.
IPSWICH	J. B. Alexander, Esq.	North Gate House.
BELFAST	Robert Patterson, Esq., M.R.I.A.	High Street.
HULL	Edmund Smith, Esq.	Hull.
CHELTENHAM	Richard Beamish, Esq., F.R.S.	Cheltenham.

Associates for the Meeting in 1857 may obtain the Volume for the Year at the same price as Members.

PROCEEDINGS OF THE FIRST AND SECOND MEETINGS, at York and Oxford, 1831 and 1832, *Published at* 13*s*. 6*d*.

CONTENTS :—Prof. Airy, on the Progress of Astronomy ;—J. W. Lubbock, on the Tides; —Prof. Forbes, on the Present State of Meteorology ;—Prof. Powell, on the Present State of the Science of Radiant Heat ;—Prof. Cumming, on Thermo-Electricity ;—Sir D. Brewster, on the Progress of Optics ;—Rev. W. Whewell, on the Present State of Mineralogy ;—Rev. W. D. Conybeare, on the Recent Progress and Present State of Geology ;—Dr. Prichard's Review of Philological and Physical Researches.

Together with Papers on Mathematics, Optics, Acoustics, Magnetism, Electricity, Chemistry, Meteorology, Geography, Geology, Zoology, Anatomy, Physiology, Botany, and the Arts; and an Exposition of the Objects and Plan of the Association, &c.

PROCEEDINGS OF THE THIRD MEETING at Cambridge, 1833, *Published at* 12*s*.

CONTENTS :—Proceedings of the Meeting ;—John Taylor, on Mineral Veins ;—Dr. Lindley, on the Philosophy of Botany ;—Dr. Henry, on the Physiology of the Nervous System ;—P. Barlow, on the Strength of Materials ;—S. H. Christie, on the Magnetism of the Earth ;—Rev. J. Challis, on the Analytical Theory of Hydrostatics and Hydrodynamics ;—G. Rennie, on Hydraulics as a Branch of Engineering, Part I. ;—Rev. G. Peacock, on certain Branches of Analysis.

Together with papers on Mathematics and Physics, Philosophical Instruments and Mechanical Arts, Natural History, Anatomy, Physiology, and History of Science.

PROCEEDINGS OF THE FOURTH MEETING, at Edinburgh, 1834, *Published at* 15*s.*

CONTENTS:—H. G. Rogers, on the Geology of North America;—Dr. C. Henry, on the Laws of Contagion; Prof. Clark, on Animal Physiology;—Rev. L. Jenyns, on Zoology;—Rev. J. Challis, on Capillary Attraction;—Prof. Lloyd, on Physical Optics;—G. Rennie, on Hydraulics, Part II.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTH MEETING, at Dublin, 1835, *Published at* 13*s.* 6*d.*

CONTENTS:—Rev. W. Whewell, on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat; — A. Quetelet, Aperçu de l'Etat actuel des Sciences Mathématiques chez les Belges;—Capt. E. Sabine, on the Phænomena of Terrestrial Magnetism.

Together with the Transactions of the Sections, Prof. Sir W. Hamilton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTH MEETING, at Bristol, 1836, *Published at* 12*s.*

CONTENTS:—Prof. Daubeny, on the Present State of our Knowledge with respect to Mineral and Thermal Waters;—Major E. Sabine, on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland;—J. Richardson, on North American Zoology;—Rev. J. Challis, on the Mathematical Theory of Fluids;—J. T. Mackay, a Comparative View of the more remarkable Plants which characterize the neighbourhood of Dublin and Edinburgh, and the South-west of Scotland, &c.;—J. T. Mackay, Comparative Geographical Notices of the more remarkable Plants which characterize Scotland and Ireland;—Report of the London Sub-Committee of the Medical Section on the Motions and Sounds of the Heart;—Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart;—Report of the Dublin Committee on the Pathology of the Brain and Nervous System;—J. W. Lubbock, Account of the Recent Discussions of Observations of the Tides;—Rev. B. Powell, on determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media;—Dr. Hodgkin, on the Communication between the Arteries and Absorbents;—Prof. Phillips, Report of Experiments on Subterranean Temperature;—Prof. Hamilton, on the Validity of a Method recently proposed by G. B. Jerrard, for Transforming and Resolving Equations of Elevated Degrees.

Together with the Transactions of the Sections, Prof. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTH MEETING, at Liverpool, 1837, *Published at* 16*s.* 6*d.*

CONTENTS:—Major E. Sabine, on the Variations of the Magnetic Intensity observed at different points of the Earth's Surface;—Rev. W. Taylor, on the various modes of Printing for the Use of the Blind;—J. W. Lubbock, on the Discussions of Observations of the Tides;—Prof. T. Thomson, on the Difference between the Composition of Cast Iron produced by the Cold and Hot Blast;—Rev. T. R. Robinson, on the Determination of the Constant of Nutation by the Greenwich Observations;—R. W. Fox, Experiments on the Electricity of Metallic Veins, and the Temperature of Mines;—Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them;—Dr. G. O. Rees, Report from the Committee for inquiring into the Analysis of the Glands, &c. of the Human Body;—Second Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart;—Prof. Johnston, on the Present State of our Knowledge in regard to Dimorphous Bodies;—Lt.-Col. Sykes, on the Statistics of the Four Collectorates of Dukhun, under the British Government;—E. Hodgkinson, on the relative Strength and other Mechanical Properties of Iron obtained from the Hot and Cold Blast;—W. Fairbairn, on the Strength and other Properties of Iron obtained from the Hot and Cold Blast;—Sir J. Robison, and J. S. Russell, Report of the Committee on Waves;—Note by Major Sabine, being an Appendix to his Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface;—J. Yates, on the Growth of Plants under Glass, and without any free communication with the outward Air, on the Plan of Mr. N. J. Ward, of London.

Together with the Transactions of the Sections, Prof. Traill's Address and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTH MEETING, at Newcastle, 1838, *Published at* 15*s.*

CONTENTS :—Rev. W. Whewell, Account of a Level Line, measured from the Bristol Channel to the English Channel, by Mr. Bunt;—Report on the Discussions of Tides, prepared under the direction of the Rev. W. Whewell;—W. S. Harris, Account of the Progress and State of the Meteorological Observations at Plymouth;—Major E. Sabine, on the Magnetic Isoclinal and Isodynamic Lines in the British Islands;—D. Lardner, LL.D., on the Determination of the Mean Numerical Values of Railway Constants;—R. Mallet, First Report upon Experiments upon the Action of Sea and River Water upon Cast and Wrought Iron;—R. Mallet, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances.

Together with the Transactions of the Sections, Mr. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINTH MEETING, at Birmingham, 1839, *Published at* 13*s.* 6*d.*

CONTENTS :—Rev. B. Powell, Report on the Present State of our Knowledge of Refractive Indices, for the Standard Rays of the Solar Spectrum in different media;—Report on the Application of the Sum assigned for Tide Calculations to Rev. W. Whewell, in a Letter from T. G. Bunt, Esq.;—H. L. Pattinson, on some Galvanic Experiments to determine the Existence or Non-Existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alston Moor;—Sir D. Brewster, Reports respecting the two series of Hourly Meteorological Observations kept in Scotland;—Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle;—R. Owen, Report on British Fossil Reptiles;—E. Forbes, Report on the Distribution of Pulmoniferous Mollusca in the British Isles;—W. S. Harris, Third Report on the Progress of the Hourly Meteorological Register at the Plymouth Dockyard.

Together with the Transactions of the Sections, Rev. W. Vernon Harcourt's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15*s.*

CONTENTS :—Rev. B. Powell, Report on the recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on "The Motions and Sounds of the Heart," by the London Committee of the British Association, for 1839–40;—Prof. Schönbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839 and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838 to Nov. 1st, 1839;—W. Thompson, Report on the Fauna of Ireland: Div. *Vertebrata*;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13*s.* 6*d.*

CONTENTS :—Rev. P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M. D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific co-operation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Committee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of

a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles; Reports on the Determination of the Mean Value of Railway Constants:—D. Lardner, LL.D., Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s*. 6*d*.

CONTENTS:—Report of the Committee appointed to conduct the co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on tho Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s*.

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and of Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W. Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Œconomy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes; —Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines; —Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves; —L. Agassiz, Rapport sur les Poissons Fossiles de l'Agile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

CONTENTS:—Seventh Report of a Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843; —R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phænomena of Animals and Vegetables;—Fifth Report ot the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s*.

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water:—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phænomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables; with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phænomena of Plants and Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15*s.*

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phænomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and

History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840, to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phænomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Œconomical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phænomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phænomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Œconomy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Œconomy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations;—John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake

Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phænomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phænomena (continued); —Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships; Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55; —Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS;—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores; —Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phænomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

List of those Members of the British Association for the Advancement of Science, to whom Copies of this Volume [for 1857] *are supplied gratuitously, in conformity with the Regulations adopted by the General Committee.* [*See pp.* xvii. & xviii.]

HONORARY MEMBER.

HIS ROYAL HIGHNESS THE PRINCE CONSORT.

LIFE MEMBERS.

Adair, Lt.-Col. Robert A. Shafto, F.R.S., 7 Audley Square, London.
Adams, John Couch, M.A., D.C.L., F.R.S., F.R.A.S., Pembroke College, Cambridge.
Ainsworth, Thomas, The Flosh, Egremont, Cumberland.
Aldam, William, Frickley Hall near Doncaster.
Allecock, Samuel, Rushulme Place near Manchester.
Allen, William J. C., Secretary to the Royal Belfast Academical Institution; 8 Wellington Place, Belfast.
Allis, Thomas, Osbaldwick Hall, York.
Ambler, Henry, Watkinson Hall, Ovenden near Halifax.
Amery, John, F.S.A., Park House, Stourbridge.
Anderson, William (Yr.), Glentarkie by Strathmiglo, Fife.
Andrews, Thos., M.D., F.R.S., M.R.I.A., Vice-President of, and Professor of Chemistry in, Queen's College, Belfast.
Ansted, D. T., M.A., F.R.S. 17 Manchester Street, Manchester Square, London.
Appold, John George, F.R.S., 23 Wilson Street, Finsbury Square, London.
Archer, T. C., Professor of Botany in Queen's College, Liverpool; Higher Tranmere, Cheshire.
Armstrong, William G., F.R.S., Elswick Engine Works, Newcastle-upon-Tyne.
Arthur, Rev. William, M.A., 26 Campden Grove, Kensington, London.
Ashton, T., M.D., 81 Mosley St., Manchester.
Ashworth, Edmund, Egerton Hall, Turton near Bolton.
Atkinson, Joseph B., Cotham, Bristol.
Atkinson, Richard, jun., 31 College Green, Dublin.
Auldjo, John, F.R.S., Noel House, Kensington.
Ayrton, W. S., F.S.A., Harehills, Leeds.
Babbage, Charles, M.A., F.R.S., 1 Dorset Street, Manchester Square, London.
Babington, Charles Cardale, M.A., F.R.S., (*Local Treasurer*), St. John's College, Cambridge.
Backhouse, John Church, Blackwell, Darlington.
Baddeley, Captan Frederick H., R.E., Ceylon.
Bain, Richard, Gwennap near Truro.
Bainbridge, Robert Walton, Middleton House near Barnard Castle, Durham.
Baker, John, Dodge Hill, Stockport.
Baker, William, 63 Gloucester Place, Hyde Park, London.
Baldwin, the Hon. Robert, H. M. Attorney-General, Spadina, Co. York, Upper Canada.
Balfour, John Hutton, M.D., Professor of Botany in the University of Edinburgh, F.R.S. L. & E., F.L.S.; Edinburgh.
Ball, John, M.R.I.A., 85 Stephen's Green, Dublin.
Ball, William, Rydall, Ambleside, Westmoreland.
Barbour, Robert, Portland Street, Manchester.
Barclay, J. Gurney, Walthamstow, Essex.
Barnes, Thomas, M.D., F.R.S.E., Carlisle.
Barnett, Richard, M.R.C.S., 11 Victoria Square, Reading.
Barton, John, Bank of Ireland, Dublin.
Bashforth, Rev. Francis, B.D., St. John's College, Cambridge.
Bateman, Joseph, LL.D., F.R.A.S., J.P. for Middlesex, &c., 24 Bedford Place, Kensington, London.
Bayldon, John, Lendal, York.
Bayley, George, 2 Cowper's Court, Cornhill, London.
Beamish, Richard, F.R.S., 2 Suffolk Square, Cheltenham.
Beatson, William, Rotherham.

[It is requested that any inaccuracy in the Names and Residences of the Members may be communicated to Messrs. Taylor and Francis, Printers, Red Lion Court, Fleet Street, London.]

Beaufort, William Morris, 11 Gloucester Place, Portman Square, London.
Belcher, Capt. Sir Edw., R.N., F.R.A.S., 22 Thurloe Square, Brompton, London.
Belcombe, Henry Stephens, M.D., Minster Yard, York.
Bell, Matthew P., 245 St. Vincent Street, Glasgow.
Bennoch, Francis, Blackheath Park, Kent.
Bergin, Thomas Francis, M.R.I.A., 49 Westland Row, Dublin.
Berryman, William Richard, 6 Tamar Terrace, Stoke, Devonport.
Bickerdike, Rev. John, M.A., Leeds.
Binyon, Thomas, St. Ann's Square, Manchester.
Bird, William, 9 South Castle Street, Liverpool.
Birks, Rev. Thomas Rawson, Kelshall Rectory, Royston.
Birley, Richard, Sedgley, Prestwich, Manchester.
Birt, W. R., 11 Wellington Street, Victoria Park, London.
Blackie, W. G., Ph.D., F.R.G.S., 10 Kew Terrace, Glasgow.
Blackwall, John, F.L.S., Oakland, Llanrwst, Denbighshire.
Blackwell, Thomas Evans, F.G.S., The Grove, Clifton, Bristol.
Blake, Henry Wollaston, F.R.S., 8 Devonshire Place, Portland Place, London.
Blake, William, Bishop's Hull, Taunton.
Blakiston, Peyton, M.D., F.R.S., St. Leonard's-on-Sea.
Bland, Rev. Miles, D.D., F.R.S., 5 Royal Crescent, Ramsgate.
Blythe, William, Holland Bank, Church near Accrington.
Boddington, Benjamin, Burcher, Kington, Herefordshire.
Bodley, Thomas, F.G.S., Anlaby House, Pittville, Cheltenham.
Boileau, Sir John Peter, Bart., F.R.S., 20 Upper Brook Street, London; and Ketteringham Hall, Norfolk.
Bond, Walter M., The Argory, Moy, Ireland.
Bossey, Francis, M.D., Woolwich.
Bowerbank, James Scott, F.R.S., 3 Highbury Grove, London.
Brady, Antonio, Maryland Point, Essex.
Brady, Cheyne, M.R.I.A., 54 Upper Leeson Street, Dublin.
Brakenridge, John, Bretton Lodge, Wakefield.
Brett, John Watkins, 2 Hanover Square, London.
Briggs, Major-General John, E.I.C.S., F.R.S., 2 Tenterden Street, London.
Brisbane, General Sir Thos. Makdougall, Bart., K.C.B., G.C.H., D.C.L., President of the Royal Society of Edinburgh, F.R.S.; Brisbane, Greenock.
Brooke, Charles, M.B., F.R.S., 29 Keppel Street, Russell Square, London.
Brooks, Samuel, Market Street, Manchester.
Brooks, Thomas, (Messrs. Butterworth and Brooks,) Manchester.
Broun, John Allan, F.R.S., Astronomer to His Highness the Rajah of Travancore; Observatory, Trevandrum, India.
Brown, Samuel, F.S.S., The Elms, Larkhall Rise, Clapham, London.
Brown, Thomas, Ebbw Vale Iron Works, Abergavenny.
Brown, William, Docks, Sunderland.
Bruce, Alexander John, Kilmarnock.
Bruce, Haliday, M.R.I.A., 37 Dame Street, Dublin.
Brunel, Isambart Kingdom, D.C.L., F.R.S., 18 Duke Street, Westminster.
Buck, George Watson, Ramsay, Isle of Man.
Buckman, James, F.G.S., Professor of Botany, Royal Agricultural College, Cirencester.
Buckton, G. Bowdler, F.R.S., 38 Gloucester Place, Hyde Park Gardens, London.
Budd, James Palmer, Ystalyfera Iron Works, Swansea.
Buller, Sir Antony, Pound near Tavistock, Devon.
Bulman, John, Newcastle-upon-Tyne.
Burd, John, jun., Mount Sion, Radcliffe, Manchester.
Busk, George, F.R.S., Professor of Comparative Anatomy and Physiology to the Royal College of Surgeons of England; 15 Harley Street, Cavendish Square, London.
Butlery, Alexander W., Monkland Iron and Steel Company, Cardarroch near Airdrie.

Caird, James T., Greenock.
Campbell, Dugald, 7 Quality Court, Chancery Lane, London.
Campbell, Sir James, Glasgow.
Campbell, William, 34 Candlerigg Street, Glasgow.
Carew, William Henry Pole, Antony House near Devonport.
Carne, Joseph, F.R.S., Penzance.
Carpenter, Philip Pearsall, B.A., Academy Place, Warrington.
Carr, William, Blackheath.
Cartmell, Rev. James, B.D., F.G.S., Christ's College, Cambridge.

Cassels, Rev. Andrew, M.A., Batley Vicarage near Leeds.
Cathcart, Lieut.-General Charles Murray, Earl of, K.C.B., F.R.S.E., United Service Club, London.
Cayley, Sir George, Bart., Brompton, Yorkshire.
Challis, Rev. James, M.A., F.R.S., Plumian Professor of Astronomy in the University of Cambridge; Observatory, Cambridge.
Chambers, Robert, F.R.S.E., F.G.S., Edinburgh.
Champney, Henry Nelson, St. Paul's Square, York.
Chanter, John, 2 Arnold Terrace, Bow Road, Bromley.
Cheetham, David, Staleybridge, Manchester.
Chesney, Major-General Francis Rawdon, R.A., D.C.L., F.R.S., Ballyardle, Kilkeel, Co. Down, Ireland.
Chevallier, Rev. Temple, B.D., F.R.A.S., Professor of Mathematics and Astronomy in the University of Durham.
Chichester, Ashhurst Turner Gilbert, D.D., Lord Bishop of, 43 Queen Ann Street, Cavendish Square, London; and the Palace, Chichester.
Chiswell, Thomas, 19 Plymouth Grove, Manchester.
Christie, Samuel Hunter, M.A., F.R.S., Ailsa Villas, St Margaret's, Twickenham.
Clark, Rev. Charles, M.A., Queen's College, Cambridge.
Clark, Henry, M.D., 74 Marland Place, Southampton.
Clay, Joseph Travis, F.G.S., Rastrick near Huddersfield.
Clay, William, 4 Park Hill Road, Liverpool.
Clayton, David Shaw, Norbury, Stockport, Cheshire.
Coathupe, Charles Thornton, 3 Park Row, Bristol.
Coats, George, 6 Woodlands Terrace, Glasgow.
Coats, Peter, Woodside, Paisley.
Coats, Thomas, Fergeslie House, Paisley.
Cobbold, John Chevallier, M.P., Tower Street, Ipswich.
Cocker, Jonathan, Higher Broughton, Manchester.
Colfox, William, B.A., Bridport, Dorsetshire.
Compton, Lord Alwyne, Castle Ashby, Northamptonshire.
Compton, Lord William, 145 Piccadilly, London.
Conway, Charles, Pontnewydd Works, Newport, Monmouthshire.
Cooke, Arthur B., 6 Berkeley Place, Connaught Square, London.
Cooke, William Fothergill, Kidbrooke near Blackheath.
Corbet, Richard, Adderley, Market Drayton, Shropshire.
Cotton, Alexander, Landwade, Cambridgeshire.
Cotton, Rev. William Charles, M.A., New Zealand.
Courtney, Henry, M.R.I.A., 24 Fitzwilliam Place, Dublin.
Cox, Joseph, F.G.S., Wisbeach, Cambridgeshire.
Crampton, The Honourable Justice, LL.D., M.R.I.A., 3 Kildare Place, Dublin.
Crewdson, Thomas D., Dacca Mills, Manchester.
Crichton, William, 1 West India Street, Glasgow.
Crompton, Rev. Joseph, Norwich.
Cropper, Rev. John, Stand near Manchester.
Currer, Rev. Danson Richardson, Clifton House, York.
Curtis, John Wright, Alton, Hants.
Cuthbert, J. R.

Dalby, Rev. William, M.A., Rector of Compton Basset near Calne, Wilts.
Dalton, Rev. James Edward, B.D., Seagrove, Loughborough.
Danson, Joseph, 6 Shaw St., Liverpool.
Darbishire, Samuel D., Pendyffryn near Conway.
Daubeny, Charles Giles Bridle, M.D., LL.D., F.R.S., Regius Professor of Botany in the University of Oxford.
Davis, Sir John Francis, Bart., K.C.B., F.R.S., Hollywood, Compton Greenfield near Bristol.
Dawbarn, William, Wisbeach.
Dawes, Rev. William Rutter, F.R.A.S., Wateringbury near Maidstone, Kent.
Dawson, Christopher H., Low Moor, Bradford, Yorkshire.
Dawson, Henry, 14 St. James's Road, Liverpool.
Deane, Sir Thomas, Dundanion Castle, Cork.
De la Rue, Warren, Ph.D., F.R.S., Observatory, Cranford, Middlesex; and 110 Bunhill Row, London.
Dent, Joseph, Ribston Hall, Wetherby, York.
Devonshire, William, Duke of, M.A., LL.D., F.R.S., Devonshire House, Piccadilly, London.

Dickinson, Joseph, M.D., F.R.S., Great George Square, Liverpool.
Dikes, William Hey, F.G.S., Wakefield.
Dilke, C. Wentworth, F.G.S., 76 Sloane Street, London.
Dobbin, Leonard, jun., M.R.I.A., 27 Gardiner's Place, Dublin.
Dodsworth, Benjamin, St. Leonard's Place, York.
Dodsworth, George, Fulford near York.
Donaldson, John, Professor of the Theory of Music in the University of Edinburgh; Edinburgh.
Donkin, Thomas, F.R.A.S., Westow, Whitwell near York.
Dowden, Richard, Sunday's Well, Cork.
Ducie, Henry, Earl of, F.R.S., 4 Carlton Terrace, London; and Tortworth Court, Wootton-under-Edge.
Duncan, James, M.D., Farnham House, Finglass, Co. Dublin.
Dunlop, William Henry, Annan Hill, Kilmarnock.
Dunraven, Edwin, Earl of, F.R.S., Adare Manor, Co. Limerick; and Dunraven Castle, Glamorganshire.

Earnshaw, Rev. Samuel, M.A., Sheffield.
Eddison, Edwin, 58 Albion Street, Leeds.
Edmondston, Rev. John, Selkirk.
Edwards, J. Baker, Ph.D., Royal Institution Laboratory, Liverpool.
Egerton, Sir Philip de Malpas Grey, Bart., M.P., F.R.S., F.G.S., Oulton Park, Tarporley, Cheshire.
Ellis, Rev. Robert, A.M., Grimstone House near Malton, Yorkshire.
Ellis, Thomas Flower, M.A., F.R.S., Attorney-General of the Duchy of Lancaster; 15 Bedford Place, London.
Enys, John S., F.G.S., Enys, Cornwall.
Erle, Rev. Christopher, M.A., F.G.S., Hardwick Rectory near Aylesbury.
Evans, George Fabian, M.D., Waterloo Street, Birmingham.
Ewing, William, 209 Brandon Place, West George Street, Glasgow.
Eyre, George Edward, F.G.S., Warrens near Lyndhurst, Hants.

Fairbairn, William, C.E., F.R.S., Manchester.
Faraday, Michael, D.C.L., F.R.S., Fullerian Professor of Chemistry in the Royal Institution of Great Britain; 21 Albemarle Street, London.
Farren, Edwin James, Hanover Chambers, Buckingham St., Strand, London.
Fellows, Sir Charles, F.R.G.S., 4 Montagu Place, Russell Square, London.
Fischer, William L. F., M.A., F.R.S., Professor of Natural Philosophy in the University of St. Andrew's, Scotland.
Fleming, Colonel James, Kinlochlaich, Appin, Argyleshire.
Fleming, William, M.D., Manchester.
Fletcher, Samuel, Ardwick Place, Manchester.
Forbes, David, F.G.S., A.I.C.E., 7 Calthorpe Street, Birmingham.
Forbes, James David, LL.D., Professor of Natural Philosophy in the University of Edinburgh, Sec.R.S.E, F.R.S; Edinburgh.
Forbes, Sir John, M.D., D.C.L., F.R.S., 12 Old Burlington Street, London.
Forrest, William Hutton, Stirling.
Forster, Thomas Emerson, 7 Ellison Place, Newcastle-upon-Tyne.
Forster, William, Ballynure, Clones, Ireland.
Fort, Richard, Read Hall, Whalley, Lancashire.
Fortescue, Hugh, Earl, K.P., F.R.S., 17 Grosvenor Square, London; and Castle Hill, Southmolton.
Foster, Charles Finch, Mill Lane, Cambridge.
Foster, H. S., Cambridge.
Foster, John, M.A., The Oaks Parsonage, Loughborough, Leicestershire.
Fowler, Robert, 23 Rutland Sq., Dublin.
Fox, Charles, Trebah, Falmouth.
Fox, Joseph Hayland, Wellington, Somerset.
Fox, Robert Barclay, Falmouth.
Fox, Samuel Lindoe, Tottenham.
Frankland, Rev. Marmaduke Charles, Chowbent near Manchester.
Freeland, Humphrey William, F.G.S., The Athenæum Club, Pall Mall, London.
Frerichs, John Andrew, 1 Keynsham Bank, Cheltenham.
Frith, Richard Hastings, C.E., Terenure Terrace, Co. Dublin.
Fullarton, Allan, Greenock.
Fulton, Alexander, 7 Woodside Crescent, Glasgow.

Gadesden, Augustus William, F.S.A., Leigh House, Lower Tooting, Surrey.
Garrett, Henry, Belfast.
Gaskell, Samuel, 19 Whitehall Place, London.
Gething, George Barkley, Springfield, Newport, Monmouthshire.
Gibson, George Stacey, Saffron Walden.
Gilbart, James William, F.R.S., London and Westminster Bank, Lothbury, London.

Gladstone, George, F.C.S., Clapham Common, London.
Gladstone, John Hall, Ph.D., F.R.S., 21 Tavistock Square, London.
Goodman, John, M.D., The Promenade, Southport.
Goodsir, John, F.R.S.L. & E., Professor of Anatomy in the University of Edinburgh.
Gordon, James, 46 Park Street, Bristol.
Gordon, Rev. James Crawford, M.A., Delamont, Downpatrick, Downshire.
Gotch, Rev. Frederick William, B.A., 1 Cave Street, Bristol.
Gotch, Thomas Henry, Kettering.
Graham, Thomas, M.A., D.C.L., F.R.S., Master of the Royal Mint, London.
Grainger, John, Rose Villa, Belfast.
Gratton, Joseph, 32 Gower Street, London.
Graves, Rev. Charles, D.D, Professor of Mathematics in the University of Dublin, M.R.I.A.; 2 Trinity College, Dublin.
Graves, Rev. Richard Hastings, D.D., Brigown Glebe, Michelstown, Co. Cork.
Gray, John, Greenock.
Gray, John Edward, Ph.D., F.R.S., Keeper of the Zoological Collections of the British Museum; British Museum.
Gray, William, F.G.S. (*Local Treasurer*), Minster Yard, York.
Grazebrook, Henry, jun., 61 Canning Street, Liverpool.
Greenaway, Edward, 40 Kensington Park Gardens, Notting Hill, London.
Greswell, Rev. Richard, B.D., F.R.S., Beaumont Street, Oxford.
Griffin, John Joseph, 119 Bunhill Row, London.
Griffith, Sir Richard, Bart., LL.D., M.R.I.A., F.G.S., Fitzwilliam Place, Dublin.
Griffiths, S. Y., Oxford.
Guinness, Rev. William Smyth, M.A., Beaumont, Drumcondra, Co. Dublin.
Gutch, John James, 88 Micklegate, York.

Hall, T. B., Coggeshall, Essex.
Hallam, Henry, M.A., D.C.L., F.R.S., Trust. Brit. Mus., 24 Wilton Crescent, Knightsbridge, London.
Hamilton, Mathie, M.D., Warwick Street, Glasgow.
Hamilton, Sir William Rowan, LL.D., Astronomer Royal of Ireland, and Andrews' Professor of Astronomy in the University of Dublin, M.R.I.A., F.R.A.S.; Observatory near Dublin.
Hamilton, William John, F.R.S., For. Sec. G.S., 23 Chesham Place, Belgrave Square, London.
Hamlin, Captain Thomas, Greenock.
Harcourt, Rev. William V. Vernon, M.A. F.R.S., Bolton Percy, Tadcaster.
Hare, Charles John, M.D., 41 Brook Street, Grosvenor Square, London.
Harley, John, Ross Hall near Shrewsbury.
Harris, Alfred, Ryshworth Hall near Bingley, Yorkshire.
Harris, George William, 17 Park Street, Westminster.
Harris, Henry, Heaton Hall near Bradford.
Harrison, William, Galligreaves House near Blackburn.
Harter, William, Hope Hall, Manchester.
Hartley, Jesse, Trentham St., Liverpool.
Harvey, Joseph Charles, Youghal, Co. Cork.
Hatton, James, Richmond House, Higher Broughton, Manchester.
Haughton, William, 28 City Quay, Dublin.
Hawkins, Thomas, F.G.S., Down Court, Isle of Wight.
Hawkshaw, John, F.R.S., F.G.S., 43 Eaton Place, London.
Hawthorn, Robert, C.E., Newcastle-upon-Tyne.
Hemans, Geo. William, C.E., M.R.I.A., 32 Leinster Gardens, Hyde Park, London.
Henry, Alexander, Portland Street, Manchester.
Henry, William Charles, M.D., F.R.S., Haffield near Ledbury, Herefordshire.
Henslow, Rev. John Stevens, M.A., F.L.S., Professor of Botany in the University of Cambridge, and Examiner in Botany in the University of London; Hitcham, Bildeston, Suffolk.
Hepburn, J. Gotch, Clapham Common, Surrey.
Herbert, Thomas, Nottingham.
Heywood, Sir Benjamin, Bart., F.R.S., 9 Hyde Park Gardens, London; and Claremont, Manchester.
Heywood, James, F.R.S., 26 Palace Gardens, Kensington, London.
Heywood, Robert, Bolton.
Higgin, Edward, Liverpool.
Higson, Peter, Irwill Terrace, Lower Broughton, Manchester.
Hill, Rev. Edward, M.A., F.G.S., Sheering Rectory, Harlow.
Hill, Rowland, F.R.S., F.R.A.S., Secretary to the Post Office, London.
Hindmarsh, Frederick, F.G.S., 17 Bucklersbury, London.
Hindmarsh, Luke, Alnwick.
Hoare, Rev. George Tooker, Tandridge, Godstone.

Hoblyn, Thomas, F.R.S., White Barnes, Buntingford, Herts.
Hodgkin, Thomas, M.D., F.R.G.S., 35 Bedford Square, London.
Hodgkinson, Eaton, F.R.S., Hon. M.R.I.A., Professor of the Mechanical Principles of Engineering in University College, London; 44 Drayton Grove, Brompton, London.
Hodgson, Adam, Everton, Liverpool.
Holden, Moses, 13 Jordan Street, Preston.
Holditch, Rev. Hamnet, M.A., Caius College, Cambridge.
Holland, P. H.
Hollingsworth, John, 10 Burney Street, Greenwich.
Hone, Nathaniel, M.R.I.A., Doloughs Park, Co. Dublin.
Hopkins, William, M.A., LL.D., F.R.S., Cambridge.
Horner, Leonard, V.P.R.S., V.P.G.S., 17 Queen's Road West, Regent's Park, London.
Horsfield, George, Brampton Grove, Smedley Lane, Cheetham, Manchester.
Houldsworth, Henry, Newton Street, Manchester.
Houldsworth, John, 196 Athol Place, Bath Street, Glasgow.
Hoyle, John, Brown Street, Manchester.
Hudson, Henry, M.D., M.R.I.A., 23 Stephen's Green, Dublin.
Hull, William Darley, F.G.S., 49 Milner Square, Islington, London.
Hulse, Edward, D.C.L., All-Soul's College, Oxford.
Hunter, Thomas C., Greenock.
Hutchison, Graham, 16 Blythswood Square, Glasgow.
Hutton, Robert, M.R.I.A., F.G.S., Putney Park, Surrey.
Hutton, William, North Terrace, West Hartlepool.

Ibbetson, Captain Levett Landen Boscawen, K.R.E., F.R.S., Clifton House, Old Brompton, London.
Inman, Thomas, M.D., Rodney Street, Liverpool.

Jackson, James Eyre, Tullydory, Blackwater Town, Co. Armagh.
Jacob, John, M.D., Maryborough.
Jardine, Sir William, Bart., F.R.S.E., Jardine Hall, Applegarth, by Lockerby Dumfriesshire.
Jarratt, Rev. John, M.A., North Cave near Brough, Yorkshire.
Jee, Alfred S., 6 John Street, Adelphi, London.
Jeffray, John, 137 Sauchiehall Street, Glasgow.
Jenkyns, Rev. Henry, D.D., Professor of Divinity and Ecclesiastical History in the University of Durham; Durham.
Jenyns, Rev. Leonard, M.A., F.L.S., Upper Swainswick near Bath.
Jerram, Rev. S. John, M.A., Witney, Oxfordshire.
Jerrard, George Birch, B.A., Examiner in Mathematics and Natural Philosophy in the University of London; Long Stratton, Norfolk.
Johnson, Thomas.
Johnstone, James, Alva near Alloa, Stirlingshire.
Johnstone, Sir John Vanden Bempde, Bart., M.P., M.A., F.G.S., 27 Grosvenor Square, London.
Jones, Christopher Hird, 2 Castle Street, Liverpool.
Jones, Major Edward.
Jones, Josiah, 2 Castle Street, Liverpool.
Jones, Robert, 2 Castle Street, Liverpool.
Jones, R. L., Great George Square, Liverpool.
Joule, Benjamin, jun., New Bailey Street, Salford, Manchester.
Joule, James Prescott, LL.D., F.R.S., Oakfield, Moss-side near Manchester.
Joy, Rev. Charles Ashfield, Hopwas, Tamworth, Staffordshire.
Jubb, Abraham, Halifax.

Kay, John Robinson, Boss Lane House, Bury, Lancashire.
Kay, Rev. William, D.D., Lincoln College, Oxford.
Kelsall, Henry, Rochdale, Lancashire.
Ker, Robert, Auchinraith, Glasgow.
Knowles, Edward R. J., 23 George Street, Ryde, Isle of Wight.
Knowles, William, Newport, Monmouthshire.
Knox, G. James, 2 Finchley New Road, St. John's Wood, London.

Laming, Richard, Hazelgrove, Hayward's Heath, Sussex.
Langton, William, Manchester.
Lansdowne, Henry, Marquis of, K.G., D.C.L., F.R.S., Trust. Brit. Mus., 54 Berkeley Square, London; and Bowood Park, Wiltshire.
Larcom, Colonel Thomas A., R.E., LL.D., F.R.S., M.R.I.A., Phœnix Park, Dublin.

La Touche, David Charles, M.R.I.A., Castle Street, Dublin.
Laurie, James, Langholm near Carlisle.
Leatham, Charles Albert, Wakefield.
Leatham, Edward Aldam, Wakefield.
Leather, John Towlerton, Leventhorpe Hall near Leeds.
Lee, John, LL.D., F.R.S., 5 College, Doctor's Commons, London; and Hartwell House near Aylesbury.
Lee, John Edward, Caerleon, Monmouthshire.
Leese, Joseph, jun., Glenfield, Altrincham.
Leeson, Henry B., M.A., M.D., F.R.S., The Maples, Bonchurch, Isle of Wight.
Lefroy, Lt.-Colonel John Henry, R.A., F.R.S., War Office.
Legh, George Cornwall, M.P., F.G.S., High Legh, Cheshire.
Leinster, Augustus Frederick, Duke of, M.R.I.A., 6 Carlton House Terrace, London.
Lemon, Sir Charles, Bart., F.R.S., 46 Charles Street, Berkeley Square, London; and Carclew near Falmouth.
Lemon, James, jun., Ardville, Belfast.
Lindsay, Charles, 10½ Addle Hill, Upper Thames Street, London.
Lindsay, John H., 317 Bath St., Glasgow.
Lingard, John R., F.G.S., Stockport, Cheshire.
Lister, Joseph Jackson, F.R.S., Upton, Essex.
Lloyd, George, M.D., F.G.S., Stank Hill near Warwick.
Lloyd, Rev. Humphrey, D.D., LL.D., F.R.S. L. and E., V.P.R.I.A., Trinity College, Dublin.
Lloyd, John Buck, Liverpool.
Lobley, James Logan, 87 Brunswick Road, Liverpool.
Locke, John, Rathmines, Dublin.
Lockey, Rev. Francis, Swainswick near Bath.
Loftus, William Kennett, F.G.S.
Logan, Rev. Thomas, M.A., Rutherglen, Glasgow.
Logan, Sir William Edmond, F.R.S., F.G.S., Director of the Geological Survey of Canada; Montreal.
Londesborough, Albert Denison, Lord, K.C.H., F.R.S., 8 Carlton House Terrace, London; and Grimstone Park, Tadcaster, Yorkshire.
Lubbock, Sir John William, Bart., M.A., F.R.S., Mansion House Street, London; and High Elms, Farnborough.
Lubbock, John, F.R.S., 11 Mansion House Street, City, London; and High Elms, Farnborough.
Luckcock, Howard, Oak Hill, Edgbaston, Birmingham.
Lundie, Cornelius, Percy Main, Newcastle-upon-Tyne.
Lyell, Sir Charles, M.A., LL.D., D.C.L., F.R.S., F.G.S., 53 Harley Street, Cavendish Square, London.

Macadam, Stevenson, Ph.D., Surgeons' Hall, Edinburgh.
McAll, Rev. Edward, Rector of Brighstone, Newport, Isle of Wight.
McAndrew, Robert, F.R.S., Isleworth House, Isleworth, Middlesex.
MacBrayne, Robert, 8 Woodside Crescent, Glasgow.
McConnel, James, Manchester.
Mackenzie, James, Glentore.
Macrory, Adam John, Duncairn, Belfast.
Macrory, Edmund, 7 Fig Tree Court, Temple, London.
McCulloch, George, M.D., Cincinnati, United States.
MacDonnell, Rev. Richard, D.D., Provost of Trinity College, Dublin, M.R.I.A.; Dublin.
McEwan, John, Glasgow.
Macfie, R. A., 72 Upper Parliament Street, Liverpool.
McGee, William, M.D., 10 Donegall Square East, Belfast.
MacIver, Charles, Abercromby Square, Liverpool.
Mackinlay, David, Pollockshields, Glasgow.
Malcolm, Frederick, 4 Sion College, London Wall, London.
Mallet, Robert, F.R.S., M.R.I.A., 11 Bridge Street, Westminster; and Delville near Dublin.
Manchester, James Prince Lee, D.D., Lord Bishop of, F.R.S., Palace, Manchester.
Marshall, James Garth, M.A., F.G.S., Headingley near Leeds.
Martin, Francis P. Brouncker, 14 Bruton Street, Berkeley Square, London.
Martindale, Nicholas, Peter Lane, Hanover Street, Liverpool.
Martineau, Rev. James, Liverpool.
Mason, Thomas, York.
Mather, Daniel, 58 Mount Pleasant, Liverpool.
Mather, John, 58 Mount Pleasant, Liverpool.
Maxwell, James C., Professor of Natural Philosophy, Marischal Coll., Aberdeen.
Maxwell, Sir John, Bart., F.R.S., Pollok House, Renfrewshire.

Maxwell, Robert Percival, Finebrogue, Downpatrick, Ireland.
Mayne, Rev. Charles, M.R.I.A., 22 Upper Merrion Street, Dublin.
Meadows, James, York Place, Rusholme near Manchester.
Meynell, Thomas, Yarm, Yorkshire.
Michell, Rev. Richard, B.D., Prælector of Logic, Lincoln College, Oxford.
Miller, Patrick, M.D., Exeter.
Miller, William Allen, M.D., F.R.S., Professor of Chemistry in King's College, London.
Mills, John Robert, Bootham, York.
Milne, David, M.A., F.R.S.E., Edinburgh.
Milner, W. Ralph, Wakefield, Yorkshire.
Milner, William, Liverpool.
Moffat, John, C.E., Ardrossan.
Moore, John Carrick, M.A., F.R.S., F.G.S., 4 Hyde Park Gate, Kensington Gore, London; and Corswall, Wigtonshire.
Moore, John Schank, Professor of the Law of Scotland in the University of Edinburgh, F.R.S.E., 19 Great King Street, Edinburgh.
Moore, Rev. William Prior, The College, Cavan, Ireland.
Morris, Rev. Francis Orpen, B.A., Nafferton Vicarage near Driffield, Yorkshire.
Morton, Francis, Hermitage, Oxton, Cheshire.
Moss, W. H., Kingston Terrace, Hull.
Murchison, Sir Roderick Impey, G.C.St.S., M.A., D.C.L., F.R.S., V.P.G.S., Pres.R.G.S., Director-General of the Geological Survey of the United Kingdom; 16 Belgrave Square, London.
Murray, John, C.E., 11 Great Queen Street, Westminster, London.
Muspratt, James Sheridan, Ph.D., College of Chemistry, Liverpool.

Napier, Captain Johnstone (74th Regiment), The Villa, Poughill, Bude, Cornwall.
Nasmyth, James, F.R.A.S., Patricroft near Manchester.
Newall, Robert Stirling, Gateshead-upon-Tyne.
Newlands, James, 2 Clare Terrace, Liverpool.
Newman, F. William, Professor of Latin in University College, London; 7 Park Village East, Regent's Park, London.
Newman, William, Darley Hall, near Barnsley, Yorkshire.
Nicholls, John Ashton, F.R.A.S., Ardwick Place, Manchester.
Nicholson, Cornelius, F.G.S., The Hill, Hornsey near London.
Nicholson, John A., M.D., M.R.I.A., Balrath, Kells, Co. Meath.

Oldham, Thomas, M.A., F.R.S., M.R.I.A. 19 Pembroke Road, Dublin.
O'Reardon, John, M.D., 35 York Street, Dublin.
Orpen, Charles Edward H., M.D., Cape of Good Hope.
Osler, A. Follett, F.R.S., Birmingham.
Oxford, Samuel Wilberforce, D.D., Lord Bishop of, F.R.S., 61 Eaton Place, London.

Palmer, William, Headington Hill near Oxford.
Parker, Alexander, M.R.I.A., William Street, Dublin.
Parker, Charles Stewart, Liverpool.
Pasley, Major-General Sir Charles William, Royal Engineers, K.C.B., D.C.L., F.R.S., 12 Norfolk Crescent, Hyde Park, London.
Patterson, Robert, M.R.I.A., (*Local Treasurer*), College Square North, Belfast.
Pattinson, Hugh Lee, F.R.S., Scots House, Gateshead-upon-Tyne.
Pearsall, Thomas John, F.C.S.
Peckover, Alexander, F.R.G.S., Wisbeach, Cambridgeshire.
Peckover, Algernon, F.L.S., Wisbeach, Cambridgeshire.
Peckover, Daniel, Woodhall near Bradford, Yorkshire.
Peckover, William, F.S.A., Wisbeach, Cambridgeshire.
Pedler, Lieut.-Colonel Philip Warren, Mutley House near Plymouth.
Peel, George, Soho Iron Works, Ancoats, Manchester.
Perigal, Frederick, 28 Hereford Square, Brompton, London.
Peters, Edw., Temple Row, Birmingham.
Petit, Rev. John Louis, 9 New Square, Lincoln's Inn, London.
Philips, Edward, 35 Church Street, Manchester.
Philips, Herbert, 35 Church Street, Manchester.
Philips, Mark, The Park near Manchester.
Phillips, John, M.A., LL.D., F.R.S., Pres.G.S., Reader in Geology in the University of Oxford, (*Assistant General Secretary*); Magdalen Bridge, Oxford.
Phillipps, Sir Thomas, Bart., M.A., F.R.S., Middle Hill near Broadway, Worcestershire.

Philpott, Rev. Henry, D.D., Master of St. Catharine's Hall, Cambridge.
Pike, Ebenezer, Besborough, Cork.
Pitt, George, 11 Pembridge Villas, Bayswater, London.
Pollexfen, Rev. John Hutton, M.A., Rector of St. Runwald's, Colchester.
Pontey, Alexander, Plymouth.
Poppelwell, Matthew, Rosella Place, Tynemouth.
Porter, Henry John.
Portlock, Major-General Joseph Ellison, R.E., LL.D., F.R.S., 58 Queen's Gardens, Hyde Park.
Pounden, Captain Landsdale, Junior United Service Club, London; and Kildare Street Club, Dublin.
Powell, Rev. Baden, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford; 6 Stanhope Street, Hyde Park Gardens, London; and Oxford.
Poynter, John E., Clyde Neuck, Uddingston.
Pratt, Samuel Peace, F.R.S., F.G.S., 27 Coleman Street, London.
Preston, R. Berthon, 10 Abercrombie Square, Liverpool.
Prestwich, Joseph, F.R.S., Treas. G.S., 2 Suffolk Lane, City, London.
Pretious, Thomas, Royal Dockyard, Pembroke.
Price, Rev. Bartholomew, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford; Pembroke College, Oxford.
Pritchard, Andrew, 2 St. Mary's Place, Canonbury, London.
Prower, Rev. J. M., M.A., Swindon, Wiltshire.
Pumphrey, Charles, Rock Mill, Stroud, Gloucestershire.

Radford, William, M.D., Sidmount, Sidmouth.
Ramsay, Sir James, Bart., F.G.S., Bamff House, Perthshire.
Ramsay, William, M.A., F.S.S., Professor of Humanity in the University of Glasgow, (*Local Treasurer*); The College, Glasgow.
Rance, Henry, Cambridge.
Ransome, Robert, Iron Foundry, Ipswich.
Rawlins, John, Birmingham.
Rawlinson, Colonel Sir H. C., K.C.B., F.R.S., 21 Langham Place, London.
Rawson, Thomas William, Saville Lodge, Halifax.
Read, W. H. Rudston, M.A., F.L.S., Hayton near Pocklington, Yorkshire.
Reade, Rev. Joseph Bancroft, M.A., F.R.S., Stone Vicarage, Aylesbury.
Redfern, Peter, M.D., Lecturer in Anatomy and Physiology in the University of Aberdeen; 2 Crown Place East, Aberdeen.
Richardson, Sir John, C.B., M.D., LL.D., F.R.S., Lancrigg, Grasmere, Westmoreland.
Riddell, Lieut.-Colonel Charles J. B., R.A., F.R.S., 1 Clarence Place, The Common, Woolwich.
Roberts, Richard, Globe Works, Manchester.
Robinson, John, Shamrock Lodge, Athlone, Ireland.
Robson, Rev. John, D.D., Glasgow.
Roget, Peter Mark, M.D., F.R.S., 18 Upper Bedford Place, Russell Square, London.
Ross, Rear-Admiral Sir James Clark, R.N., D.C.L., F.R.S., Aston House, Aston Abbots, Aylesbury.
Rowland, John, 30 Terminus Road, Brighton.
Rowney, Thomas H., M.D., College Laboratory, Glasgow.
Rowntree, Joseph, Pavement, York.
Rowntree, Joseph, Newtown, Leeds.
Rushout, Capt. the Hon. George, M.P., F.G.S., 10 Bolton Street, Piccadilly, London.
Russell, Norman Scott, 37 Great George Street, Westminster.
Russell, William J., Ph.D., Derwent Lodge, Chad Road, Edgbaston, Birmingham.
Ryland, Arthur, Birmingham.

Sabine, Major-General Edward, R.A., D.C.L., Treas. and V.P.R.S., (*General Secretary*), 13 Ashley Place, Westminster.
Salt, C. F., 88 Canning Street, Liverpool.
Salter, Thomas Bell, M.D., F.L.S., Ryde, Isle of Wight.
Sanders, William, F.G.S., (*Local Treasurer*), Park Villa, West Park, Bristol.
Satterthwaite, Michael, M.D., Lindow Grove, Alderley near Wilmslow, Cheshire.
Schemman, J. C., Hamburgh.
Schofield, Robert, 1 Gresham Street, City, London.
Scholes, T. Seddon, 16 Dale Street, Leamington.
Scholey, William Stephenson, M.A., Clapham, London.
Scholfield, Edward, M.D., Doncaster.

Sedgwick, Rev. Adam, M.A., F.R.S., Woodwardian Professor of Geology in the University of Cambridge, and Canon of Norwich; Trinity College, Cambridge.
Shaen, William, 8 Bedford Row, London.
Sharp, William, F.R.S., Rugby.
Shaw, C. Wright, Russell St., Liverpool.
Sherrard, David Henry, 88 Upper Dorset Street, Dublin.
Shortrede, Captain Robert, F.R.A.S., H.E.I.C.'s Service, Aden.
Sillar, Zechariah, M.D., Rainford near Liverpool.
Simpson, Rev. Samuel, Douglas, Isle of Man.
Simpson, T., M.D., Minster Yard, York.
Sirr, Rev. Joseph D'Arcy, D.D., M.R.I.A., Castle Hill, Winchester.
Slater, Wm., Princess St., Manchester.
Sleeman, Philip, Windsor Terrace, Plymouth.
Smith, Rev. Geo. Sidney, D.D., M.R.I.A., Professor of Biblical Greek in the University of Dublin; Aughalurcher, Five-mile-Town, Co. Tyrone.
Smith, Henry J. Stephen, Balliol College, Oxford.
Smith, James, Berkeley House, Seaforth near Liverpool.
Smith, John, Welton Garth near Hull.
Smith, Rev. J. D., Kingstown near Dublin.
Smith, Rev. Philip, B.A., Head Master of Mill Hill School, Hendon, Middlesex.
Smith, Robert Mackay, Bellevue Crescent, Edinburgh.
Smyth, C. Piazzi, F.R.S., Astronomer Royal of Scotland, Professor of Practical Astronomy in the University of Edinburgh; 1 Hill Side Crescent, Edinburgh.
Smyth, John, jun., M.A., C.E., Milltown, Banbridge, Ireland.
Solly, Edward, F.R.S., Professor of Chemistry to the Horticultural Society of London; Holme Court, Isleworth, near London.
Solly, Samuel Reynolds, M.A., F.R.S., Surge Hill, King's Langley, Herts.
Sopwith, Thomas, F.R.S., 43 Cleveland Square, London.
Spence, Joseph, Pavement, York.
Spiers, R. J., 14 St. Giles's Street, Oxford.
Spottiswoode, W., M.A., F.R.S., 12 James Street, Buckingham Gate, London.
Sprague, Thomas Bond, St. John's College, Cambridge.
Squire, Lovell, Falmouth.
Stainton, James Joseph, F.L.S., Lewisham, Kent.
Stanger, Joshua, Keswick, Cumberland.
Stanley, Lord, M.P., St. James's Square, London.
Stewart, Henry Hutchinson, M.D., M.R.I.A., 71 Eccles Street, Dublin.
Stokes, George Gabriel, M.A., D.C.L., Sec.R.S., Lucasian Professor of Mathematics in the University of Cambridge; Pembroke College, Cambridge.
Strickland, Arthur, Bridlington Quay, Yorkshire.
Strickland, Charles, Loughglyn, Ballaghadereen, Ireland.
Sykes, Colonel, William H., M.P., F.R.S., 47 Albion Street, Hyde Park, London.
Symonds, Frederick, F.R.C.S., Oxford.
Symons, William, Dunster, Somerset.

Tate, A., 41 Upper Sackville St., Dublin.
Tayler, Rev. John James, B.A., Principal and Professor of Ecclesiastical History in Manchester New College, London; 22 Woburn Square, London.
Taylor, James, Culverlands near Reading.
Taylor, John, F.R.S., (*General Treasurer*), 6 Queen Street Place, Upper Thames Street; and Chester Terrace, Regent's Park, London.
Taylor, John, jun., F.G.S., 6 Queen St. Place, Upper Thames Street, London.
Taylor, Richard, F.G.S., 6 Queen Street Place, Upper Thames Street, London.
Taylor, Richard, F.L.S., Red Lion Court, Fleet Street, London.
Tennant, James, F.G.S., Professor of Mineralogy and Geology in King's College, London; 149 Strand, London.
Thomson, Corden, M.D., Sheffield.
Thomson, James, M.A., C.E., 16 Donegall Place, Belfast.
Thomson, James Gibson, Edinburgh.
Thomson, William, M.A., LL.D., F.R.S., Professor of Natural Philosophy in the University of Glasgow; The College, Glasgow.
Thornton, Samuel, The Elms, Highgate, Birmingham.
Thorp, The Venerable Thomas, D.D., Archdeacon of Bristol; Kemerton near Tewkesbury.
Tidswell, Benjamin K., Brown Street, Manchester.
Tindal, Captain, R.N., Western Branch Bank of England, Burlington Gardens, London.
Tinné, John A., F.R.G.S., Briarly Aigburth, Liverpool.
Townsend, Richard E., Springfield, Norwood.
Trevelyan, Arthur, Wallington, Northumberland.

Tuckett, Francis Fox, Frenchay, Bristol.
Tulloch, James, F.R.S., 16 Montagu Place, Russell Square, London.
Turnbull, Rev. Thomas Smith, M.A., F.R.S., Blofield, Norfolk.
Tweedy, Wm. Mansell, Truro, Cornwall.
Tyndall, John, Ph.D., F.R.S., Professor of Natural Philosophy in the Royal Institution of Great Britain, Albemarle Street, London.

Vallack, Rev. Benj. W. S., St. Budeaux near Plymouth.
Vance, Rev. Robert, 16 Montpelier Hill, Dublin.
Vernon, John, Hayman's Green, West Derby, Liverpool.
Vivian, H. Hussey, Swansea.

Waldegrave, The Hon. Granville, 26 Portland Place, London.
Walker, John, Weaste House, Pendleton, Manchester.
Walker, Joseph N., F.L.S., Caldeston near Liverpool.
Walker, Rev. Robt., M.A., F.R.S., Reader in Experimental Philosophy in the University of Oxford; Wadham College, Oxford; and Culham Vicarage, Abingdon.
Walker, Thomas, 10 York Street, Manchester.
Warburton, Henry, M.A., F.R.S., 45 Cadogan Place, Sloane Street, London.
Ward, William Sykes, F.C.S., Claypit House, Leeds.
Waterhouse, J., F.R.S., Halifax, Yorkshire.
Watson, Henry Hough, Bolton-le-Moors.
Way, J. Thomas, Professor of Chemistry, Royal Agricultural Society of England, Hanover Square, London.
Webb, Rev. Thomas William, M.A., Cloisters, Gloucester.
Western, T. B., Felix Hall, Kelvedon, Essex.
Westhead, Joshua Proctor, York House, Manchester.
Westley, William, 24 Regent Street, London.
Whewell, Rev. William, D.D., F.R.S., Master of Trinity College, Cambridge; Lodge, Cambridge.
Whitehouse, Wildman, 16 Hyde Vale, Blackheath.
Whiteside, James, M.A., Q.C., M.P., 2 Mountjoy Square, Dublin.
Whittey, John Irwine, LL.D., Civil and Mining Engineer, 15 Henrietta Street, Dublin.
Whitworth, Joseph, F.R.S., Manchester.
Wickenden, Joseph, F.G.S., Birmingham.
Willert, Paul Ferdinand, Manchester.
Williams, Caleb, Micklegate, York.
Williams, Rev. D., D.C.L., Warden of New College, Oxford.
Williams, William, 6 Rood Lane, Fenchurch Street, London.
Williamson, Alex. W., Ph.D., F.R.S., Professor of Practical Chemistry in University College, London; 12 Provost Road, Haverstock Hill, London.
Williamson, Rev. William, B.D., Datchworth Rectory near Stevenage.
Wills, William, F.G.S., Edgbaston near Birmingham.
Wilson, Alexander, F.R.S., 34 Bryanstone Square, London.
Wilson, Capt. F., Dallam Tower, Milnthorpe, Westmoreland.
Wilson, John, Bootham, York.
Wilson, John, jun., West Hurlet near Glasgow.
Wilson, Sumner, Southampton.
Wilson, Thomas, M.A., Crimbles House, Leeds.
Wilson, William Parkinson, M.A., Professor of Pure and Applied Mathematics in the University of Melbourne.
Winsor, F. A., 57 Lincoln's Inn Fields, London.
Wollaston, Thomas Vernon, M.A., F.L.S., 10 Hereford Street, Park Lane, London.
Wood, Rt. Hon. Sir Charles, Bart., M.P., Admiralty, and Hickleston Hall, Doncaster.
Wood, Rev. H. H., M.A., F.G.S., Queen's College, Oxford.
Wood, John, St. Saviourgate, York.
Wood, Rev. William Spicer, M.A., Oakham, Rutlandshire.
Woodd, Charles H. L., F.G.S., Hillfield, Hampstead, London.
Woodhead, G., Mottram near Manchester.
Worcester, Henry Pepys, D.D., Lord Bishop of, 24 Grosvenor Place, London.
Wormald, Richard, 12 Little Tower Street, London.
Worthington, Robert, Cheetham Hill near Manchester.
Worthington, Rev. Alfred William, B.A., Mansfield.
Wright, Robert Francis, Hinton Blewett, Somersetshire.

Yarborough, George Cooke, Camp's Mount, Doncaster.
Yorke, Colonel Philip, F.R.S, 89 Eaton Place, Belgrave Square, London.
Younge, Robert, M.D., Greystones near Sheffield.

ANNUAL SUBSCRIBERS.

Aldridge, John, M.D., M.R.I.A., 20 Ranelagh Road, Dublin.
Alison, William P., M.D., F.R.S.Ed., Emeritus Professor of the Practice of Medicine in the University of Edinburgh; 44 Heriot Row, Edinburgh.
Allman, George James, M.D., F.R.S., M.R.I.A., Professor of Natural History in the University of Edinburgh; 3 Hope Park, Edinburgh.
Andrews, William, M.R.I.A., 18 Leinster Street, Dublin.
Anster, John, LL.D., M.R.I.A., Regius Professor in Civil Law in the University of Dublin; 5 Lower Gloucester Street, Dublin.
Argyll, George Douglas, Duke of, F.R.S., Campden Hill, Kensington, London, and Inverary Castle, Inverary, Scotland.
Armstrong, William Jones, M.A., Mount Irwin, Tynan, Co. Armagh.

Baily, William H., F.G.S.
Baines, Samuel, Brighouse near Huddersfield.
Barker, John, M.D., M.R.I.A., 48 Waterloo Road, Dublin.
Barlow, Peter William, F.R.S., 26 Great George Street, Westminster.
Barrington, Edward, Fassaroe, Bray, Ireland.
Barrington, Richard, Trafalgar Terrace, Kingstown, Dublin.
Barton, Folliot W., Clonelly, Co. Fermanagh.
Beattie, Joseph, London.
Becker, Ernest, Buckingham Palace, London.
Beke, Charles T., Ph.D., F.S.A., Mauritius.
Benson, Charles, M.D., M.R.I.A., 11 Fitzwilliam Square West, Dublin.
Bewley, Charles, Cope Street, Dublin.
Billings, Robert William, 3 St. Mary's Road, Canonbury, London.
Bolster, Rev. John A., Cork.
Boult, Joseph, 24 North John Street, Liverpool.
Brazier, James S., Marischal College, Aberdeen.
Brazill, Thos., 12 Holles Street, Dublin.
Brewster, Sir David, K.H., D.C.L., F.R.S, V.P.R.S. Ed., Principal of the United College of St. Salvator and St. Leonard, St. Andrew's.
Bright, Charles T., The Cedars, Harrow Weald, Middlesex.
Bright, Edward B., 36 Hope Street, Liverpool.
Brooke, Edward, Marsden House, Stockport, Cheshire.
Brooke, Peter William, Marsden House, Stockport, Cheshire.
Brown, John, 2 Bloomfield Villas, Tufnell Park West, London.
Brownlee, James, 173 St. George's Road, Glasgow.
Burk, J. Lardner, LL.D., 2 North Great George Street, Dublin.
Busby, John, 9 Trafalgar Terrace, Monkstown, Ireland.
Butcher, Rev. S., D.D., M.R.I.A., Regius Professor of Divinity in the University of Dublin; 13 Fitzwilliam Square West, Dublin.
Butt, Isaac, Leeson Street, Dublin.

Cairnes, William, Trinity College, Dublin.
Callan, Rev. N. J., D.D., Professor of Natural Philosophy in Maynooth College, Ireland.
Calvert, Professor F. Crace, F.C.S., Royal Institution, Manchester.
Cameron, Charles A., M.D., 17 Ely Place, Dublin.
Carte, Alexander, M.D., M.R.I.A., Royal Dublin Society, Dublin.
Carter, Richard, C.E., Long Carr, Barnsley, Yorkshire.
Churchill, F., M.D., M.R.I.A., 15 Stephen's Green, Dublin.
Clarendon, F. Villiers, 11 Blessington Street, Dublin.
Clarke, Edward S., M.D., M.R.I.A., Educational Office, Marlborough St., Dublin.
Claudet, A., F.R.S., 107 Regent Street, London.
Clements, Henry, Galway.
Colles, William, M.D., Stephen's Green, Dublin.
Cooper, Sir Henry, M.D., 7 Charlotte Street, Hull.
Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology in Queen's College, Cork.
Cottam, Samuel, Manchester.
Crampton, Rev. Josiah, Enniskillen, Ireland.
Crawford, G. Arthur, M.A., 9 Lower Merrion Street, Dublin.

Crolly, Rev. George, Maynooth College, Maynooth, Ireland.
Crum, Walter, F.R.S., Thornliebank near Glasgow.
Cull, Richard, 13 Tavistock Street, Bedford Square, London.
Cunningham, William A., Bank, 94 Mosley Street, Manchester.
Curry, Eugene, M.R.I.A., 2 Portland Street North, Dublin.
Curtis, Arthur H., 6 Trinity College, Dublin.

Dale, John A., M.A., 11 Holywell Street, Oxford.
Dashwood, Charles, Thornage near Thetford, Norfolk.
Da Silva, Johnson, Percy Cross House, Fulham near London.
Davy, Edmund W., M.D., F.R.S., M.R.I.A., Professor of Chemistry to the Royal Dublin Society, Dublin.
Deane, Henry, Clapham, London.
Dennis, J. C., F.R.A.S., 122 Bishopsgate Street, London.
Denvir, Right Rev. Cornelius, Bishop of Down and Connor, Belfast.
Dicker, J. R., 29 Exchange Alley North, Liverpool.
Dickson, Peter, 28 Upper Brook Street, London.
Dodds, Thomas W., C.E., Rotherham.
Domvile, William C., Thorn Hill, Bray, Dublin.
Dove, Hector, 71 Hope Street, Glasgow.
Downing, S., LL.D., M.R.I.A., Professor of Civil Engineering in the University of Dublin.
Du Noyer, George V., M.R.I.A., 51 Stephen's Green, Dublin.
Dwyer, Henry L., M.A., M.B., 67 Upper Sackville Street, Dublin.

Elliot, Robert, Wolflee, Hawick.
Ellis, Hercules, Lisnaroe, Clones, Ireland.
Evans, Griffith F. D., M.D., St. Mary's, Bedford.
Everest, Colonel George, Bengal Artillery, F.R.S., 10 Westbourne Street, Hyde Park, London.

Farrelly, Rev. Thomas, Royal College, Maynooth, Ireland.
Ferguson, James, Auchinheath and Craignethan Gas Coal Works, Lesmahago, Glasgow.
Ferguson, Samuel, M.R.I.A., 20 North Great George Street, Dublin.
Fielding, James, Sowerby Bridge near Halifax.
Fitzgerald, Lord Otho, 13 Dominick Street, Dublin.
Fitzpatrick, Thomas, M.D., 31 Lower Baggot Street, Dublin.
Foster, George C., B.A., F.C.S., University College, London.
Fowler, Richard, M.D., F.R.S., Salisbury.
Fraser, James P., 58 Buccleuch Street, Glasgow.
Frazer, Daniel, 9 Mansfield Place, Glasgow.

Gages, Alphonse, Museum of Irish Industry, Dublin.
Gassiot, John P., V.P.R.S., Clapham Common, London.
Gerard, Henry, 10 Rumford Place, Liverpool.
Gibson, Thomas F., 124 Westbourne Terrace, Hyde Park, London.
Gilbert, J. T., M.R.I.A., Blackrock, Dublin.
Good, John, 50 City Quay, Dublin.
Gordon, Samuel, M.B., M.R.I.A., 11 Hume Street, Dublin.
Gough, The Hon. G. S., B.A., M.R.I.A., Rathronan House, Clonmel, Ireland.
Grant, Robert, M.A., F.R.A.S., Royal Astronomical Society, Somerset House, Strand, London.
Gray, John, M.D., Rathgar, Dublin.
Green, J. Reay, 3 Granby Row, Dublin.
Greenhalgh, Thomas, Astley House near Bolton-le-Moors.
Greenwood, William, Stones, Todmorden, Lancashire.
Greg, Robert Philips, F.G.S., (*Local Treasurer*), Norcliffe Hall near Manchester.
Grubb, Thomas, M.R.I.A., Bank of Ireland, Dublin.
Gwynne, Rev. John, St. Columbe's College, Dublin.

Hall, Hugh F., Richmond Villa, New Brighton, Cheshire.
Halpin, George, C.E., North Wall, Dublin.
Hamilton, Charles W., M.R.I.A., 40 Dominick Street, Dublin.
Hancock, John, Lurgan, Co. Armagh.
Hancock, William J., 74 Lower Gardiner Street, Dublin.
Hancock, W. Neilson, LL.D., M.R.I.A., 74 Lower Gardiner Street, Dublin.
Harcourt, Rev. L. Vernon, West Dean House, Chichester.
Harkness, Robert, F.R.S., F.G.S. Professor of Geology in Queen's College, Cork.
Hartnup, John, F.R.A.S., Observatory, Liverpool.

Haughton, S. Wilfred, Grand Canal Street, Dublin.
Haughton, Rev. S., M.A., F.R.S., M.R.I.A., Professor of Geology in Trinity College, Dublin.
Hawkes, William, Eagle Foundry, Birmingham.
Hayden, Thomas, M.D., 30 Harcourt Street, Dublin.
Hector, James, M.D., 1 Northumberland Street, Edinburgh.
Hennessy, Henry, F.R.S., M.R.I.A., Professor of Natural Philosophy in the Catholic University of Ireland, Dublin.
Hennessy, John Pope, Inner Temple, London.
Hepburn, Robert, 8 Davis Street, Berkeley Square, London.
Hervey, The Rev. Lord Arthur, Ickworth, Suffolk.
Higgins, Rev. Henry H., M.A., Rainhill, Liverpool.
Hill, John, Tullamore, Ireland.
Hill, Laurence, Port Glasgow.
Hill, William, F.R.A.S., Worcester.
Hincks, Rev. Edward, D.D., Killyleagh, Ireland.
Holland, Edward, M.P., Dumbleton, Evesham.
Hooton, Jonathan, 80 Great Ducie Street, Manchester.
Howell, Henry H., Museum of Practical Geology, Jermyn Street, London.
Hudson, Robert, F.R.S., Clapham Common, London.
Huggon, William, 30 Park Row, Leeds.
Hunt, Robert, F.R.S., Keeper of Mining Records, Museum of Practical Geology, Jermyn Street, London.
Huntington, Frederick, F.R.C.S.Engl., 19 George Street, Hull.
Hutchinson, J. C., Carrick-on-Shannon, Ireland.
Hutton, Henry D., 1 Nelson Street, Dublin.

Jemison, William H., 7 Drumcondra Terrace, Dublin.
Johnston, A. Keith, 4 St. Andrew Square, Edinburgh.
Jones, C. W., 7 Grosvenor Place, Cheltenham.
Jones, Rev. Henry Halford, Cemetery, Manchester.
Jones, John, 28 Chapel Street, Liverpool.

Kavanagh, James W., Grenville, Rathgar, Ireland.
Kay, Alexander, Atherton Grange, Wimbledon Park, Surrey.
Kaye, Robert, Mill Brae, Moodiesburn, Glasgow.
Kelly, John J., 38 Mount Pleasant Sq., Dublin.
Kennedy, George A., M.D., M.R.I.A., 15 Talbot Street, Dublin.
Kennedy, Lt.-Colonel J. P., London.
Kent, William T., M.R.I.A., M.R.D.S., 51 Rutland Square, Dublin.
Kenworthy, J. Ryley, Guernsey.
Ker, André A. Murray, Newbliss House, Dublin.
Kinehan, John R., M.D., Donnybrook, Dublin.
Kirkwood, Anderson, 246 Sauchie' all Street, Glasgow.

Lankester, Edwin, M.D., F.R.S., 8 Savile Row, London.
Latham, R. G., M.D., F.R.S., Greenford, Middlesex.
Law, Hugh, 4 Great Denmark Street, Dublin.
Lawson, James A., M.R.I.A., 27 Upper Fitzwilliam Street, Dublin.
Leach, Captain, R.E., Mountjoy, Phœnix Park, Dublin.
Lister, John, M.D., F.G.S., Shibden Hall near Halifax.
Liveing, G. D., St. John's College, Cambridge.
Longfield, Rev. George, M.A., M.R.I.A., 25 Trinity College, Dublin.
Lord, Edward, York Street, Todmorden.
Low, Professor David, F.R.S.E., Mayfield by Trinity, Edinburgh.
Lyons, Robert D., M.R.I.A., 31 Upper Merrion Street, Dublin.

Macauley, James W., M.D., Royal Hospital, Dublin.
McCausland, Dominick, M.R.I.A., 12 Fitzgibbon Street, Dublin.
Maclaren, Charles, Moreland Cottage, Grange Loan, Edinburgh.
M Laren, John, Spring Bank, Dunoon.
Madden, Richard R., M.D., M.R.I.A., Rathmines, Dublin.
Malahide, Talbot de, Lord, Malahide Castle, Malahide, Ireland.
Mallett, Dr. J. W., University of Alabama, United States.
Marriott, William, Leeds Road, Huddersfield.
Maughan, Rev. J. D. Gooch, Frescati, Dublin.
May, Charles, F.R.S., 3 Great George Street, Westminster.
Mayne, William Annesley, Upper Leeson Street, Dublin.

Melly, Charles Pierre, Riversley, Liverpool.
Miles, Rev. C. P., M.D., 14 Buckingham Terrace, Glasgow.
Millar, George M., M.R.I.A., Susanvale, Kilmainham, Dublin.
Mirrlees, J. Buchanan, 94 West Street, Tradeston, Glasgow.
Moffat, T., M.D., F.R.A.S., Hawarden, Chester.
Moir, James, 174 Gallowgate, Glasgow,
Moore, Arthur, Alpha House, Drumcondra, Ireland.
Moore, Rev. Dr., Clontarf, Dublin.
Morton, George H., 9 London Road, Liverpool.
Moses, Marcus, 4 Westmoreland Street, Dublin.
Muir, William, Britannia Works, Manchester.
Mullins, M. Bernard, M.A., C.E., 1 Fitzwilliam Square South, Dublin.
Murray, B. A., 4 High Street, Dublin.
Murray, William, F.R.S.E., F.G.S., 160 West George Street, Glasgow.

Napier, Rt. Hon. Joseph, M.R.I.A., 36 Mountjoy Square, Dublin.
Neale, Edward V., West Wickham, Kent.
Neild, William, Mayfield, Manchester.
Neville, John, C.E., M.R.I.A., Dundalk.
Newmarch, William, Secretary to the Globe Insurance, Cornhill, London.
Nuling, Alfred, 4 Wilton Terrace, Dublin.

Odling, William, M.B. Lond., F.C.S., Professor of Practical Chemistry, Guy's Hospital, London; Kennington Road, London.
O'Donovan, John, M.R.I.A., 36 Upper Buckingham Street, Dublin.
O'Donnavan, W. John, 2 Cloisters, Temple, London.
O'Hagan, John, 20 Kildare St., Dublin.
O'Kelly, Mathias J., Dalkey, Ireland.
Oldham, James, C.E., Austrian Chambers, Hull.
Outram, Thomas, Greetland near Halifax.
Owen, James H., C.E., M.R.I.A., Parkhouse, Sandymount, Dublin.

Peach, Charles W., Custom House, Wick.
Pengelly, William, F.G.S., Lamorna, Torquay.
Percy, John, M.D., F.R.S., Museum of Practical Geology, Jermyn St., London.
Petrie, William, Ecclesbourne Cottage, Woolwich.
Phayre, George, Blakeney Terrace, Sandymount, Dublin.
Pilkington, Henry M., Co. Westmeath, Ireland.
Plunkett, Thomas, Ballybrophy House, Borris-in-Ossory, Ireland.
Pochin, Henry Davis, Quay Street, Salford.
Potchett, Rev. William, M.A., The Vicarage, Grantham.
Power, Sir James, Bart., Edernine, Enniscorthy, Ireland.

Ramsay, Andrew C., F.R.S., Local Director of the Geological Survey of Great Britain; Museum of Practical Geology, Jermyn Street, London.
Rankin, Rev. Thomas, Huggate, Yorkshire.
Rankine, W. J. Macquorn, C.E., LL.D., F.R.S. L. & E., 59 St. Vincent Street, Glasgow.
Reid, Robert, M.D., M.R.I.A., Kingstown near Dublin.
Roberton, James, Gorbals Foundry, Glasgow.
Roberts, John, 101 Upper Parliament Street, Liverpool.
Roberts, Michael, Trinity College, Dublin.
Robinson, C. B., The Shrubbery, Leicester.
Ronalds, Francis, F.R.S.
Ross, David, LL.B., Drumbrain Cottage, Dublin.
Round, Daniel George, Hange Colliery near Tipton, Staffordshire.
Russell, Rev. Professor C. W., D.D., St. Patrick's College, Maynooth.

Sanders, Gilbert, M.R.I.A., 2 Foster Place, Dublin.
Salmon, Rev. George, D.D., M.R.I.A., Trinity College, Dublin.
Scallan, James Joseph, 77 Harcourt Street, Dublin.
Scott, Robert H., 1 Salem Place; and 5 Trinity College, Dublin.
Shaw, Norton, M.D., Secretary to the Royal Geographical Society, London; 15 Whitehall Place, London.
Shewell, John T., Rushmere, Ipswich.
Sidney, Frederick J., M.D., M.R.I.A., 19 Herbert Street, Dublin.
Siegfried, Rudolph T., 4 Lennox Street, Dublin.
Siemens, C. William, 1 Kensington Terrace, Kensington, London.
Sleddon, Francis, 2 Kingston Terrace, Hull.
Sloper, George Elgar, jun., Devizes.
Smith, Aquila, M.D., M.R.I.A., 121 Lower Baggot Street, Dublin.

Smith, Robert Angus, Ph.D., 20 Grosvenor Square, Manchester.
Smith, William, C. E., 10 Salisbury Street, Adelphi, London.
Snow, John, M.D., Sackville Street, London.
Sorby, Henry Clifton, F.G.S., Broomfield, Sheffield.
Spence, Peter, Pendleton Alum Works, Manchester.
Spence, William, F.R.S., V.P.L.S., 18 Lower Seymour Street, Portman Sq., London.
Spence, W. B., 18 Lower Seymour Street, Portman Square, London.
Stack, Thomas, M.A., Regius Professor of Greek in the University of Dublin, 23 Trinity College, Dublin.
Steel, William E., M.D., 15 Hatch Street, Dublin.
Stevelly, John, LL.D., Professor of Natural Philosophy in Queen's College, Belfast.
Stewart, Balfour, 13 Rutland Square, Edinburgh.
Stoney, Bindon B., M.R.I.A., 89 Waterloo Road, Dublin.
Stoney, G. Johnstone, M.A., Galway.
Stuart, William, 1 Rumford Place, Liverpool.
Stubs, Joseph, Park House, Frodsham, Cheshire.
Sullivan, William K., Ph.D., Museum of Irish Industry, Dublin.

Talbot, William Hawkshead, Wrightington near Wigan.
Tartt, W. Macdowal, Sandford Place, Cheltenham.
Taylor, William Edward, Enfield near Accrington.
Tennison, Edw. King, M.R.I.A., Kildare Street Club House, Dublin.
Terry, John, 15 Albion Street, Hull.
Teschemacher, E. F., 1 Highbury Park North, London.
Thorburn, Rev. William Reid, M.A., Starkies, Bury, Lancashire.
Tombe, Rev. H. J., Ballyfree, Ashford, Co. Wicklow.
Townsend, Rev. Richard, 33 College, Dublin.
Turnbull, John, Bonhill House, Dumbartonshire.
Tuton, Edward S., Lime Street, Liverpool.

Varley, Cornelius, 7 York Place, High Road, Kentish Town, London.
Voelcker, J. Ch. Augustus, Ph.D., F.C.S., Professor of Agricultural Chemistry, Royal Agricultural College, Cirencester.

Walker, Charles V., F.R.S., Fernside Villa, Red Hill near Reigate.
Walker, John James, M.A., 2 Trinity College, Dublin.
Waller, Edward, Lisenderry, Aughnacloy, Ireland.
Walsh, Albert J., 89 Harcourt Street, Dublin.
Ward, John S., Sunderland.
Warington, Robert, F.C.S., Apothecaries' Hall, London.
Watt, William, Flax Works, Bedford Street, Belfast.
Watts, John King, F.R.G.S., St. Ives, Huntingdonshire.
Widdup, S., Penzance, Killurn, Co. Wexford.
Wilkinson, George, Monkstown, Ireland.
Williams, Rev. James, D.D., M.R.I.A., Llanfeirwynghowny, Holyhead.
Williamson, Benjamin, Trinity College, Dublin.
Willock, Rev. W. N., D.D., Cleenish, Enniskillen, Ireland.
Wilson, J. Moncrieff, 9 College Green, Dublin.
Woodall, Captain John Woodall, St. Nicholas House, Scarborough.
Woolley, Rev. J., LL.D., H.M. Dockyard, Portsmouth.
Woolley, Thomas Smith, South Collingham, Newark.
Wornell, George, 2 Park Crescent, Oxford.
Worthy, G. S., St. James' Barton, Bristol.
Wright, Edward, LL.D., M.R.I.A., 43 Dame Street, Dublin.
Wright, E. P., Museum, Trinity College, Dublin.
Wright, Thomas, F.S.A., 14 Sydney St., Brompton, London.

Yates, Edward, 30 Compton Terrace, Islington, London.
Yeats, John, F.R.G.S., Leicester House, Peckham, London.

Plate 1.

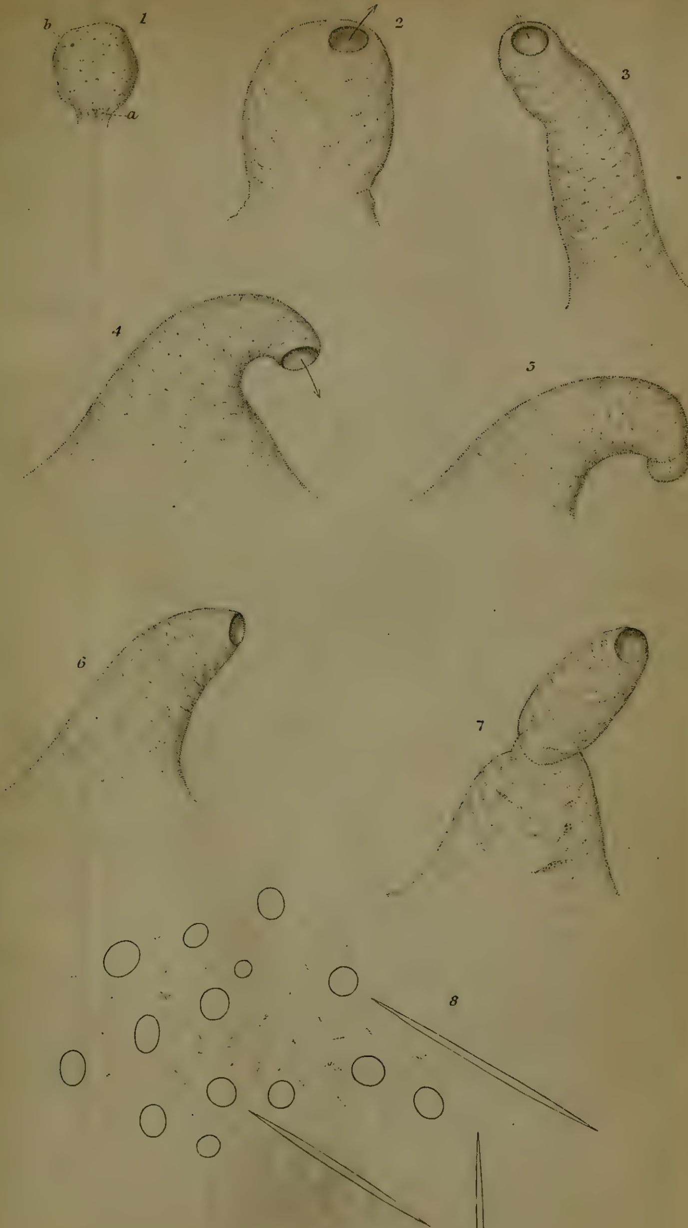
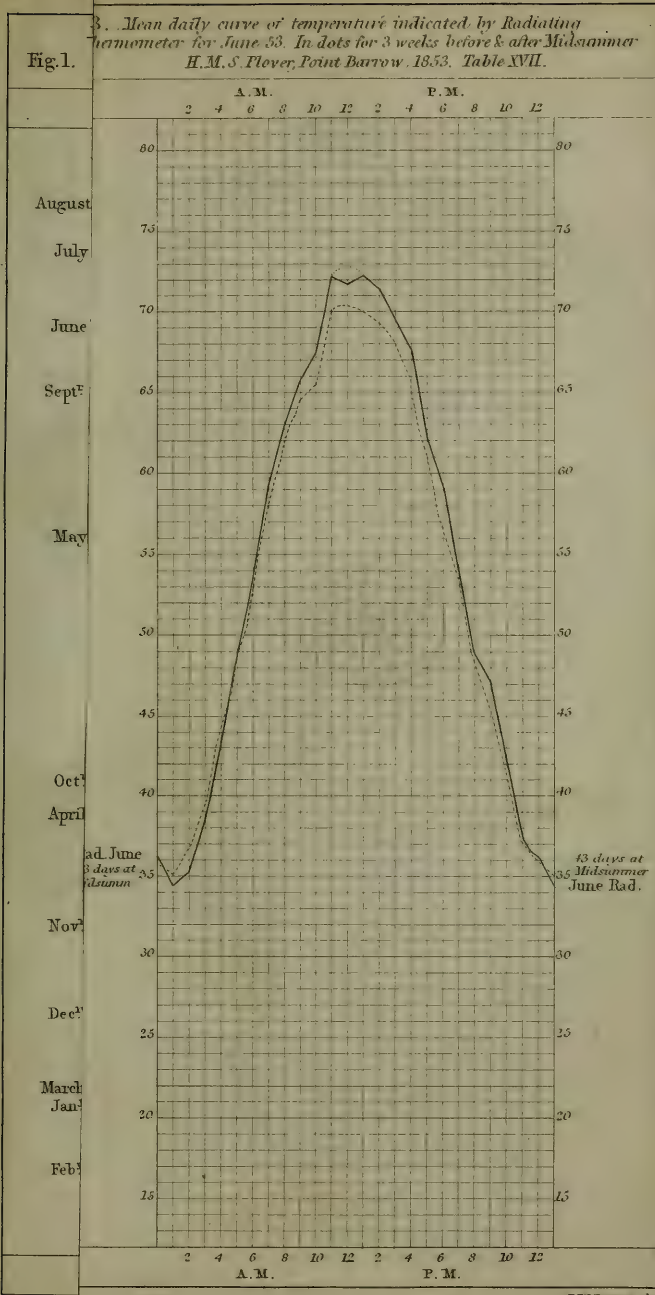


Fig. 1.



J. W. Lowry sc.

[illegible] Temperatures; H.M.S. Plover; Point Barrow [illegible]

Fig. 1 — Mean daily curves of temperature for the several months. Point Barrow Lat. 71 21 N Long. 156 17 W deduced from Table XIV

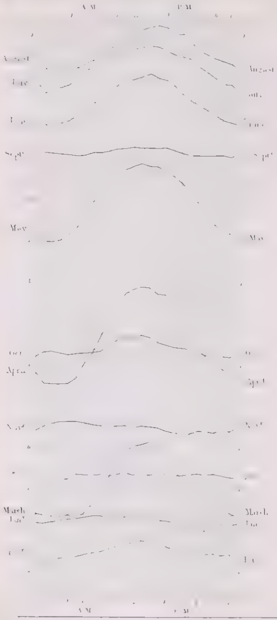


Fig. 2 — Mean d[illegible] curves of temperature for the Se[illegible] the Half Years & the Year Point Barrow 1852 3 4 H M S Plover — from Ta[illegible] XV

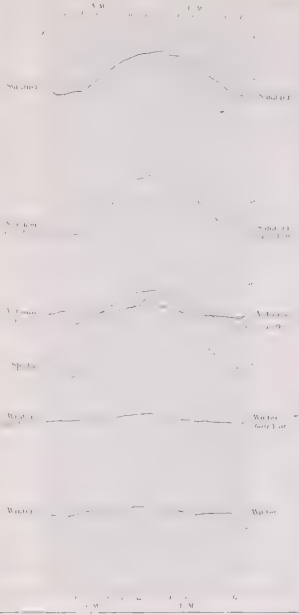
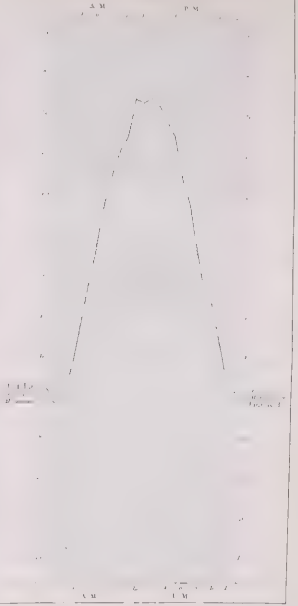


Fig. 3 — Mean daily curve of tempera[illegible] Radiating [illegible] June 53 In dots for 3 weeks before & after Midsummer H M S Plover Point Barrow 1853 Table XVII



J H Lowry sc

27th Report Brit.

1

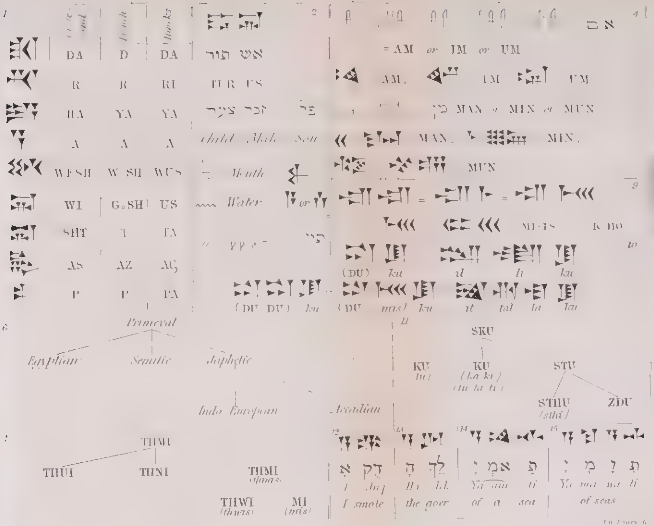
V

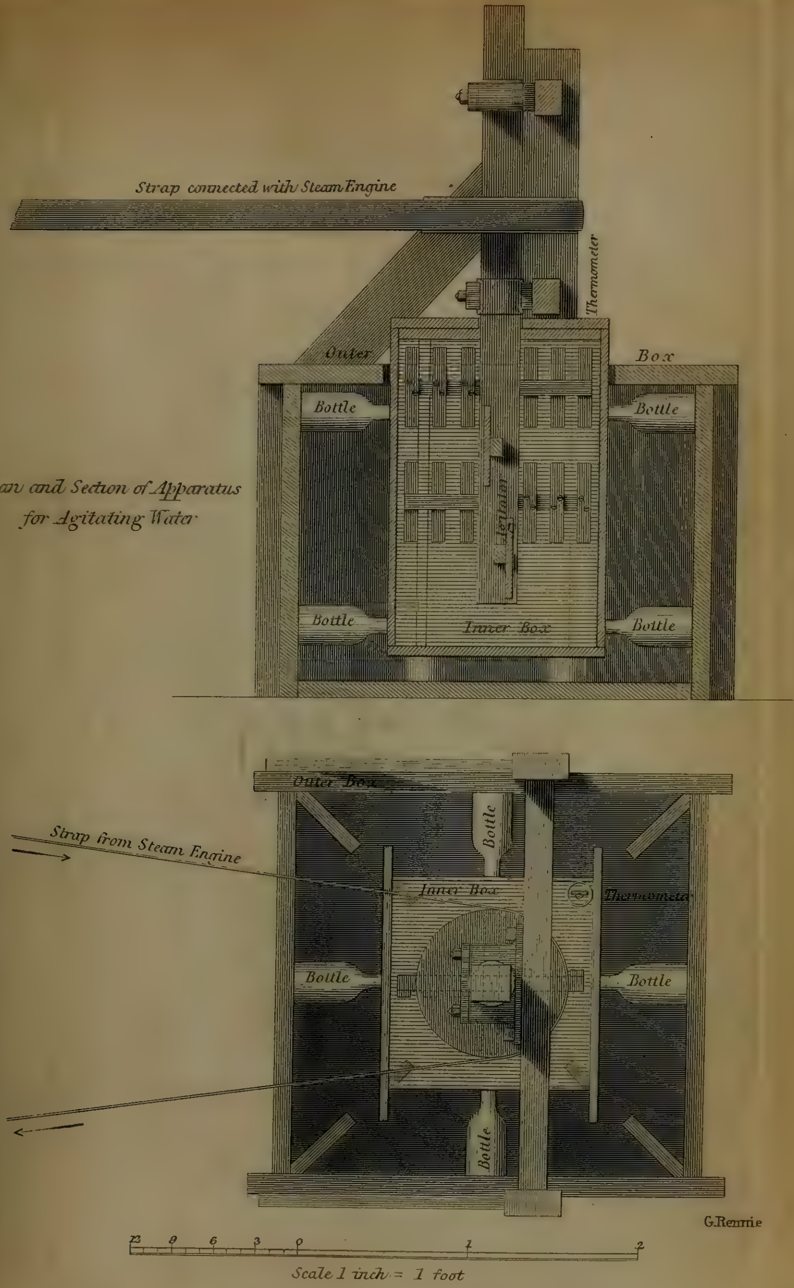
6

Egypt

7

TH


DA D DA
R R RI
HA YA YA
A A A
WESH W SH WUS
WI G.SH US
SHT T TA
AS AZ AÇ
P P PA
אש תור
TUR US
זכר צער
Child Male Son
Mouth
Water
= AM or IM or UM
AM. IM UM
MAN or MIN or MUN
MAN. MIN.
MUN
MI-IS K BO
(DU) ku il li ku
(DU DU) ku (DU mas) ku it tal la ku
Primeval
Egyptian
Semitic
Japhetic
Indo European
Accadian
SKU
KU
KU (ka ki) (tu ta ti)
STU
STHU (sthi)
ZDU
THMI
THUI
THNI
THMI (thmis)
THWI (thwis)
MI (mis)
I smote
the goer
of a sea
of seas



Plan and Section of Apparatus for Agitating Water

G. Rennie

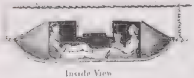
CORRUGATED GALVANIZED IRON BOAT AND LIFE CARS;

WITH THE MACHINERY FOR THEIR MANUFACTURE,

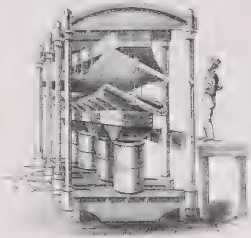
Corrugated Boat Company, London.

Outside View

LIFE CAR



Inside View



DIES FOR METALLIC BOATS

Worked by the Hydraulic Press

SHIP'S QUARTER BOAT

Whale Boat Style